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A Technical Guide to Urban and Community Forestry

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Introduction

Trees growing within cities and towns form a forest-an urban forest. But urban trees require special attention, because they are expected to exist within the urban environment. With its infrastructure of streets, sidewalks, curbs, buried utilities, overhead power lines and buildings, the urban environment places tremendous stresses on trees. With proper care, trees become assets which grow in value over time. Without care, tree value declines, eventually becoming a liability to the community. *The Technical Guide to Urban Forestry* was produced to help communities develop, manage and protect their urban forest resources. The purpose of this publication is to provide technical information about growing trees in the relatively adverse urban environment.

This guide is a sequel to *An Introductory Guide to Community and Urban Forestry in Washington, Oregon and California*. The two publications have been designed to complement each other. Together they provide introductory and technical information regarding urban forestry programs and projects. Both guides were produced in response to requests from local officials and professional tree managers.

The need for tree management is never clearer than when urban development eliminates a significant stand of trees, or even a single well placed specimen. Sometimes trees are lost inadvertently, resulting from a lack of information. For example, roots are a tree's most vulnerable part, yet heavy equipment routinely runs over roots. By the time the tree starts to show signs of physical deterioration, five to ten years may have passed. Other times trees are killed intentionally as developers "land-scrape" before construction. This approach portrays an attitude that trees have little or no value in developed areas, Those who guide local development need to understand urban stress factors and the role they play in the premature death of trees.

The topics covered in this guide include: tree values, principles of tree growth, planning, tree selection, site preparation, planting and early care of trees, maintenance of established trees, handling trees affected by development, utility forestry, and the politics of municipal tree care. This guide is intended for use by citizens, government decision makers, land developers, and workers out on the streets. Like the original *Introductory Guide*, this *Technical Guide* is written for anyone in the private or public sectors who cares enough about their environment to see that trees in their community are planted, valued and protected.

Tree pruning involves not only knowledge of tree growth, but technical expertise with equipment and supplies as well as strength and athletic agility.

The *Technical Guide* was written by a team of professionals identified on the last page. This group of researchers, educators and practitioners from throughout Washington, Oregon and California are dedicated to providing information on the urban forest resource. Their volunteer efforts reflect the need for people everywhere to contribute their energy and knowledge to make cities more livable for trees.

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Produced by
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A Technical Guide to Urban and Community Forestry in Washington, Oregon and California

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Values of Urban Trees

The basis for the value of an urban tree could be emotional, aesthetic, or it could be strictly utilitarian. However, people seldom perceive value as strictly aesthetic or monetary. There is often substantial overlap that makes "value" difficulty to classify. In many communities, public spending on tree care and management reflects an approximate value of trees. Spending patterns that go unchallenged, especially among an informed public, indicate the value people associate with trees.

The following categories describe different values that people place on trees. They are arranged primarily by their measurability. The least measurable values are discussed first.

Psychological and Aesthetic Values

Although difficult to gauge, uplifted spirits is one important benefit of trees. Some of the difficulty in measuring these benefits may grow out of society's decision to exclude tree values from the marketplace. Other emotion-based commodities, such as flowers, perfume, view property, prestige automobiles, and entertainment, are readily assigned monetary values. But with proper treatment, researchers can tie monetary values to the emotional benefits of trees.

The pleasure and good feelings we associate with trees may be far more practical than generally believed. Data on the connection between vegetation and human health are beginning to accumulate. For example, surgery patients who could see a grove of deciduous trees recuperated faster and required less pain-killing medicine than matched patients who viewed only brick walls. And, prisoners with cells overlooking green landscapes used prison health facilities significantly less than prisoners whose cells provided views of other prison facilities. The vaguely expressed "enjoyment" people associate with trees may be partly a subconscious sign of substantial health benefits.

Social Values

In Oakland, California, a neighborhood tree planting program generated community identity, cooperation, and benefits similar to those reported for urban gardening. After coming together to plant trees, Oakland residents continued working together with "paint-up-fix-up parties", neighborhood protective societies, and community gardens.

Historic Values

Trees provide important symbolic links with the past. If a living tree is associated with important events, the tree takes on historical values unrelated to aesthetics or usefulness. For example, a community would normally value a tree that shaded the deliberations of the community's founders. A tree would also be valuable if planted by George Washington or some other important figure in history. Aside from specific events, old trees may be regarded as important simply because they have lived through eras with which we have few other connections.

Photo Credit - Lane County Museum, Eugene, Oregon, First Christian Church, 1922.

As for emotional and aesthetic values, historic values of trees depend primarily on community attitudes. If historic trees are threatened by changes, such as new buildings and street widening, the issue will usually be settled by public pressure not by market forces.

Environmental Values

People value both the aesthetic and physical quality of our environment. Trees contribute to this quality by modifying local climates, reducing noise and air pollution, and by protecting soil and water.

Climate control is one important service trees provide naturally in the landscape, but the urban landscape is far from natural. Streets, parking lots and buildings have changed the climate of urban areas by absorbing solar radiation. Water that once percolated into the soil and later evapotranspired from soil and plants now drains away or dries on the hard surfaces. These changes have increased the temperatures of cities. Compared to the surrounding rural areas, the urban "heat islands" are five to nine degrees Fahrenheit warmer (three to five degrees Celsius).

Trees help moderate the "heat island" effect. They also greatly increase human comfort: indoors or outdoors. On hot days, trees pump hundreds of gallons of water through their foliage. This water evaporates, keeping the tree and its immediate surroundings cool.

While groves of trees reduce local air temperatures, individual trees increase human comfort primarily by controlling solar radiation, not air temperature. (Radiation is the movement of heat from a warmer body, the Sun, to a cooler body, the Earth.) Trees and other vegetation shield people from direct sunlight. Trees also shade soil, pavement, buildings, and other surfaces that would absorb solar energy and then radiate that heat back to the surroundings. Without the protection of trees, city dwellers are literally surrounded by radiant heat.

At night, radiation moves heat in the opposite direction: from the relatively warm earth to the relatively cool sky. Again, tree cover steps in by blocking radiant heat loss from homes and people. Icy mornings provide evidence of this process, lawns otherwise white with frost often have green circles under the trees.

Indoor air temperatures are also affected by trees growing around buildings. During hot weather, trees reduce cooling costs by buffering high air temperatures and blocking unwanted solar energy. But during winter months, solar gain is desirable, because it cuts heating costs. To get the best balance, on the south and west sides of buildings plant deciduous trees that have thin, open branches to allow winter sun penetrate into the building. In addition, the schedule of leaf growth and leaf drop should coincide with the need for heating and cooling. Few, if any, species will meet these requirements perfectly, but it's wise to select species that give the best possible match.

Air pollution control is another way that trees improve the urban environment. The reductions in air pollution are modest, and air pollution poses some risk to the trees themselves.

Trees are fairly effective at removing both solid and gaseous particulates from the air. In one study, stands of trees reduced particulates by 9 to 13 percent, and the amount of dust reaching the ground was 27 to 42 percent less under a stand of trees than in an open area. Among gaseous pollutants, ozone, chlorine, fluorine, sulphur dioxide and PAN (peroxyacetylnitrate, a photochemical component of smog) are all absorbed by trees. In most cases, these gases also damage the trees. Unfortunately, trees remove little, if any, carbon monoxide which amounts to roughly one-half the total weight of air pollutants in this country.

Increasingly, carbon dioxide is being recognized as a "greenhouse gas" pollutant with potentially devastating consequences, such as global warming, dramatic changes in rainfall patterns, and rising sea levels that threaten flooding in coastal cities Since photosynthesis in green plants consumes carbon dioxide, plants could help to counteract the increase of this gas in the atmosphere. Rosenfeld, Martin, and Rainer report that planting urban trees could reduce heating and cooling demands enough to significantly cut fossil fuel consumption. They suggest that urban trees could be about 10 times as effective as forest trees for lowering carbon dioxide in cities.

First Christian Church, Eugene, Oregon, 1986. Although these trees are protected under the Historic Tree Ordinance, it is a tree that is no longer recommended for planting by the current administration because of thorns.

Noise pollution from highways and other sources can be reduced with trees. Used alone, trees must be planted in belts 35 to 100 feet wide to create noticeable reductions. However, earth berms can cut traffic noise by up to half, if they are tall enough to hide the source of noise and are planted with trees, shrubs, and grasses. Where this kind of adjustment to the topography is not possible, a row of trees and a solid wall reaching up to the base of the crowns will provide a similar reduction.

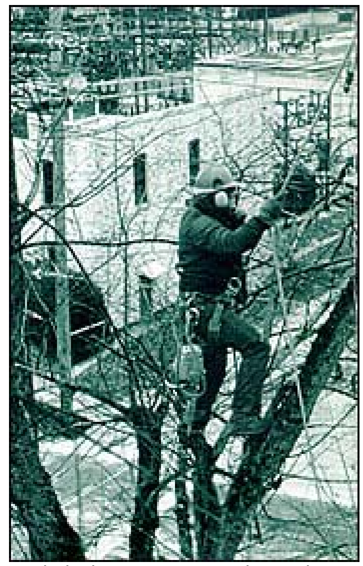
Soil and water quality are protected by trees. In urban settings, large areas are covered by buildings, pavement, and other impervious surfaces. Instead of percolating into the soil, rainwater and snowmelt are concentrated and accelerated, increasing soil erosion and silt accumulation in streams. Trees and other vegetation protect the soil from erosion. Along watercourses, roots and fallen leaves help hold the soil together and shield it against the cutting forces of surface water. Vegetation also absorbs some of the force of failing rain, so soil particles are not dislodged. And, the leaf litter that accumulates under trees creates an environment for earthworms and other organisms that help maintain soil porosity.

In studies at Pennsylvania State University, tracts of trees in municipal watersheds were used to purify partly treated sewage and protect surface waters. By adjusting sewage water application rates researchers prevented the ground water from becoming contaminated with nitrates. Ninety percent of the water applied went into recharging the underlying aquifer. Heavy metals, a worrisome component of municipal sewage, did not become a problem.

Monetary Values

Urban trees often have substantial monetary values. A number of studies have shown that real estate agents and home buyers assign between 10 and 23 percent of the value of a residence to the trees on the property. Local governments capture some of this monetary value because enhanced property values increase assessed values and the tax base.

Appraisal methods have been developed for landscape plants, including trees. The standard for estimating the monetary value of landscape vegetation, usually accepted by insurance companies, courts and public agencies, is *Valuation of Landscape Trees, Shrubs, and Other Plants: A Guide to the Methods and Procedures for Appraising Amenity Plants.* This guide was prepared by the Council of Tree and Landscape Appraisers and published by the International Society of Arboriculture, P.O. Box 71, Urbana, Illinois 61801. It is now in its seventh edition. The guide describes two methods to estimate tree value.


Technical competence and experience are required for accurate tree valuations.

The first method simply identifies the amount of money needed to replace the tree. Replacement value can be used for trees less than or equal to eight inches in diameter and commercially available in appropriate sizes. Adjust the cost of the replacement tree for condition and location. Then add the cost of planting and establishment, including labor, equipment, materials and maintenance. Costs of guarantees and a reasonable profit margin could also be added. If the purpose of the estimate is to settle a claim for the death or damage of a tree, removal and cleanup costs for the dead or damaged tree are also included.

The second method uses a formula that multiplies the cross-sectional area of the trunk by a value (currently $27) per square inch. It then adjusts this value for species, condition, and location. Trees of different sizes are measured at various distances from the ground. Tree diameter determines where the cross-sectional area is measured.

Diameter of Tree	Height of Measurement
4 inches	6 inches
8 inches	12 inches
over 8 inches	4 ½

Three factors affect tree value: species, condition, and location. Each of these factors are rated from 0 to 100 percent. This sample calculation was taken from the valuation guide:
Circumference of trunk at 4½ feet = 47 (inches)
Circumference multiplied by 0.08 = 177 (square inches)
Multiplied by current value per square = $27/inch x 177 square inches = $4,779
Multiplied by species factor, e.g., 85 percent = $4,779 x .85 = $4,062
Multiplied by condition factor, e.g., 75 percent = $4,062 x .75 = $3,046
Multiplied by location factor, e.g., .80 = $3,046 x .80 = $2,437
Value of tree = $2,437

Regardless of the method, determining the adjustment factors for species, condition, and location requires technical competence and experience. A tree valuation is only as credible as the arborist who makes the determination.

The value of a particular species or variety can be looked up in an established tree listings or judged by a local arborist. Value is often affected by local usage.

Physical condition is also a factor' regardless of the kind or size of the plant. Parts deformed by crowding, storm damage, fire, insect damage, disease or other cause are primary concerns when judging condition. Careful inspection should reveal these and other factors.

Plant location also affects value, especially when it is near buildings, utility lines or other plants. Plants used in planned landscapes often have higher appraised values than those growing wild.

Appraising a landscape plant requires considerable time on the site for looking at the tree, its environment, measuring and examining its parts, collecting samples, taking photo graphs, and asking questions of people living nearby. In addition, the process requires decisions based on specialized knowledge of plant pathology, aesthetics, ornamental horticulture, and tree physiology. Appraisers often call on other experts for consultation in some of these areas.

Monetary value can also be assigned to some of the benefits trees bring to the urban environment.

As mentioned earlier, sewage treatment costs could be cut by applying treated effluent to trees and other landscape plantings. Irrigating with recycled waste water reduces the need for costly evaporation ponds and sewage lagoons, as well as the dumping of municipal wastes into rivers, lakes and oceans. And, water-loving species could serve as natural water pumps for areas with high water tables.

Trees can cut energy costs, too. Trees shade buildings and pavement, which reduces the temperatures in and around buildings. By cutting air-conditioning costs, trees indirectly reduce carbon dioxide emissions equivalent to fifteen times the amount the tree alone could absorb. According to Akbari, et al., planting trees to reduce peak-load energy demand by one kilowatt-hour costs about one cent.

Three well placed trees can cut air-conditioning costs by ten to fifteen percent. For every ton of new wood that grows, about 1.8 tons of carbon dioxide is removed from the air and 1 .3 tons of oxygen is produced. Reducing carbon dioxide through tree planting costs about 0.3 to 1.3 cents per pound.

Akbari, et al., estimate that there are 100 million available tree planting spaces around American homes and businesses. Planting trees in those spaces could reduce atmospheric carbon dioxide by an estimated 18 million tons per year, and save consumers $4 billion each year.

Economics and Decision Making

In simpler times, municipal tree budgets were often increased routinely based on inflation and additional trees without close scrutiny for efficiency. increasingly, however, city budgets are strained, and tree managers must justify their funding requests.

This native vegetation was preserved to serve as a valuable buffer between buildings and parking areas.

Sound records on the costs of tree management operations help urban foresters justify budgets. However, many cities do not keep adequate records or the cost of retrieving the information manually has been too high. Fortunately, the cost of microcomputers has plummeted while their capabilities have soared. The hardware and software capable of maintaining records for thirty thousand or more trees can now be purchased for between $3,000 and $5,000.

A number of cities have computerized data systems for their trees, and increasingly good tree management software is coming on the market at reasonable prices. These systems allow tree managers to improve their organization in four ways.

First, computerized records allow managers to increase efficiency. They can identify the costs of planting and maintaining various species. Some species are much more costly to maintain than others, but differences may not be obvious without good records. Operational costs can also be tracked, and adjustments made to increase efficiency. For example, scheduled maintenance of all trees on a block costs much less per tree than requested maintenance of single trees. These cost differences may persuade decision-makers to provide the funding needed to permit more scheduled maintenance.

Second, workload projections permit jobs to be scheduled efficiently, coordinating the appropriate personnel and equipment.

Third, the value of a community's trees can be calculated. When maintenance is shown as a percentage of value, the cost of tree management should compare favorably with the costs of maintaining streets, sewers, and other assets. Over time, records should show that trees grow in value, while most other urban assets decline in value.

Fourth, budget needs can be projected and supported with local data. Most urban tree managers excel in the care and treatment of individual trees. Many have mastered the administrative and political aspects of local government. it is now time for them to use modern tools to track costs and increase efficiency.

Urban forest managers must become adept at communicating the value of urban trees, if their requests are to compete for an appropriate share of local budgets. Powerful computers that retrieve and summarize information can help them generate and communicate this information (Fig. 1).

As per your request, the following summary of the 17th Street Planting Project has been prepared:

Date of Start:	June 23, 1989
Date of Completion:	July 12, 1989
Location:	17th Street Medians from Irvington Blvd. To Frisco Street
Total Project Cost:	$19,696
Cost Breakdown:	Plant Material — $13,141 Supplies — $ 1,209 Contractual Services — $ 5,346
Total Project Man-hours:	312.75

Hours Per Activity:

Activity	Hours
Pit Preparation	54.75
Planting	52.00
Staking	48.00
Berm Building	26.50
Planning and Organization	23.25
Watering	21.25
Stake Repair	20.00
Mobilization	16.75
Mulching	13.00
Cleanup	11.25
Site Preparation	9.25
Herbicide Application	4.50
Pickup/Delivery	4.00
Fertilizing	3.50
Berm Repair	2.50
Equipment Preparation	1.00
Equipment Maintenance	.75
Tree Removal	.50
TOTAL	**312.75**

Landscape Inventory as of August 7, 1989:

Planting	Number
Sweet Gum	68
Red Maple	15
Holly	11*
Palm Island	3

*Two hollies are broken and need to be re-planted. Exact cause of breakage assumed to be vandalism.

Figure 1. One example of the king of report that can easily be prepared when work records and financial expenditures are traced on a computer.

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Basic Horticultural Principles

Basic Needs

Plant growth is a very complicated process, but it is not necessary to understand *all* the intricate details in order to successfully manage the urban forest. However, understanding the basic requirements of tree growth will help. The primary environmental factors are:

- Soil is a reservoir for nutrients and moisture, and provides mechanical support.
- Sunshine furnishes heat and light.
- Air supplies carbon dioxide and oxygen.

Plants in the wild obtain these basic needs from a complex, but finely balanced biological system. Cultivation often disturbs the natural balance. Any factor in the plant's environment that becomes less than optimum will limit its growth.

Naturally, quantity is important, but quality also affects the vigor of trees. Air pollution, construction activity, and soil compaction place stresses on trees. Healthy trees can better with stand these stresses year after year. This section describes principles of tree growth and their relationship with the environment. Knowing these basics will help the people responsible for tree management make wise decisions.

Relationship of Air and Water in the Soil

Soil provides a foundation for tree growth-structurally and biologically. Soil supports a tree's physical weight and resists the forces of wind. Soil al supplies water, air, and nutrients. The value of the soil as structural and biological support is related to soil structure.

Soil structure influences plant growth, because it affects moisture, aeration, heat transfer, and the mechanical resistance to root growth. Most people think of soil as being a mixture of solid elements, such as minerals and organic matter. But, open spaces in soil, called pores, are equally important. The size and distribution of soil pores affect the movement and availability of moisture and air through the soil.

The air-water relationship is a critical one for optimum plant growth. The number of pore spaces must be adequate and the variety of sizes appropriate. Pore size determines the relative amounts of air and water that soil will hold. Gravity quickly drains water from larger pores, making them good sources of air. Smaller pores tend to hold water against the pull of gravity, making them good for water storage. Because plants need both air and water in the soil, a good balance of large and small pore spaces is required for optimum growth.

Sand, with its open structure of many large pores, is called a "coarse" soil. Sandy soils generally drain well. They contain ample amounts of air, but little water. "Fine" clay soils drain poorly and tend to hold water in their many small pore spaces. But, pores in clay soils can be so small and hold water so tightly that tiny feeder roots cannot extract the moisture.

Organic matter in the soil affects both the physical and chemical properties of the soil. A fertile soil rich in organic matter is literally alive. Although insects and earthworms are the most obvious inhabitants, microorganisms, such as bacteria and fungi, constitute the largest population by weight in the soil community. Organic matter in the soil comes from decomposed plant and animal tissue as well as the micro-organisms themselves. Organic matter enhances the aeration and water-holding capacity of the soil. It also affects the soil's chemical properties by supplying necessary plant nutrients.

In extremely compacted soil, or soil without adequate aeration, roots are found growing on the surface of the soil where conditions are more favorable for growth.

The phrase "effective rooting depth" describes the portion of the soil where conditions are favorable for root growth-most often in the top three feet of the soil. Effective rooting depth may be limited by circumstances that restrict soil porosity or hinder plant growth. Four relatively common problems are surface crusting, high water tables, poor sub-surface drainage and claypans or hardpans.

Soil Compaction

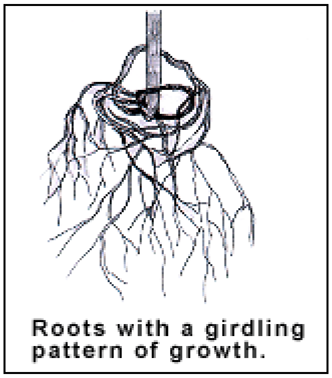
Soil compaction is the major cause of death or decline of mature trees where efforts have been made to save them. It poses a very serious threat to good soil structure. Delicate soil pores are easily crushed, decreasing their capacity for water and air movement and hindering root growth. Wet soil is particularly vulnerable, because water lubricates soil particles and loosens binding agents. Small particles slip between the larger particles, filling the pore spaces. Loose soils will compact more than tight soils, and soils that have a broad range of particle sizes can be more severely compacted than more uniform soils.

Few soils can withstand traffic without becoming severely compacted. Compaction depends not only on the amount of pressure exerted, but also on the duration and frequency of exertion. For example, the heel of a shoe exerts force per unit of area equal to that of heavy equipment (although the turning, starting and stopping of heavy equipment increases the force). Pressure spreads with depth, so the compacting effects of pedestrians and vehicles usually occur to the top four inches of the soil.

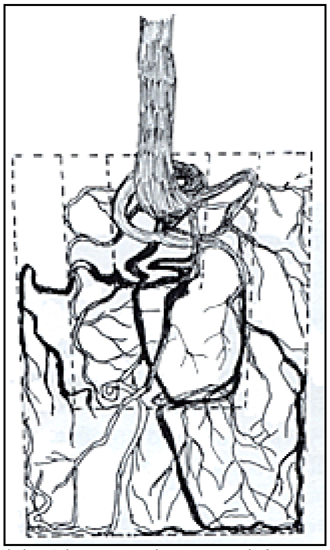
Compaction is easier to prevent than to remedy. Avoid cultivating wet soils. Keep foot and vehicle traffic over the roots to a minimum. Where traffic is necessary, confine it to a few paths that stay well away from the driplines of trees. Light-weight vehicles with large, smooth, low pressure tires compact the soil less than heavy vehicles with smaller, heavily treaded, high pressure tires. A thick, coarse mulch spread on the soil surface where travel must occur helps to disperse the load.

The Root System
A healthy root system serves multiple functions for the tree. Roots collect water and minerals from the soil, store nutrients, and anchor the tree. Fibrous roots are primarily responsible for the absorption of water and minerals from the soil. They most often grow in the top six inches of the soil. Woody roots provide a framework for anchoring the tree in the ground. They support the weight of the trunk and branches, including leaves, snow and ice. And, wind pressure adds to the load.

Woody roots radiate out horizontally and vertically, decreasing in size as they get farther from the trunk. Woody roots seldom penetrate the soil deeper than three feet. Because they are relatively shallow, roots are vulnerable to damage from activities on the surface. It's important to be aware of roots, because they are not easily seen, and structural deficiencies often remain unnoticed until the top of the tree dies back or the entire tree falls over.

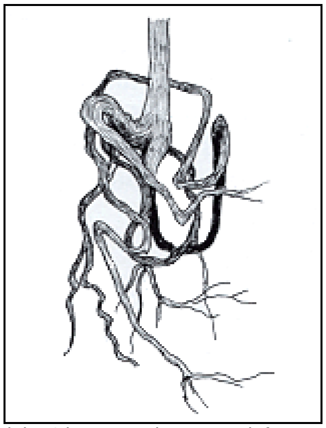


(Fig. 2)



(Fig. 2.) Zones where root defects are commonly found in container grown trees.

Root defects commonly occur in two forms (Fig. 2). When roots grow in a circle around the root mass it's called girdling. Roots may also be kinked into a characteristic "j-hook" growth pattern. Improper treatment in the nursery often causes these types of defects. To avoid problems, inspect the roots in the nursery before purchasing trees. Girdling roots may also occur after the tree is planted into the landscape. This happens when roots grow around the edge of the planting pit instead of out into the field soil. A lack of structural integrity in the root system may cause the planting to fail early in the tree's life or much later, but failure is sure to occur.



(Fig. 2.) Zones where root defects are commonly found in container grown trees.

Figure 2. Types of root defects and the zones within the root mass where they may be found.

Structural Strength of Tree Crowns

A tree's crown must be strong enough to withstand wind forces, and carry the weight of snow, ice, and branches covered with thousands of leaves. To assess the structural strength of a crown, look at these characteristics: the spacing of lateral branches along the main trunk, the presence of a clearly dominant leader or main trunk, trunk taper near the ground, and angle of branch attachment.

A tree with branches spread out along the trunk generally has better structure than one with all its branches growing close together on the trunk. A clearly dominant leader or main trunk provides a strong framework-called a scaffold-that supports lateral branches. Several leaders of similar size offer a weaker scaffold. Even round, oval, and vase shaped trees that commonly have more than one leader should show a clear hierarchy of leader sizes. This distinction of leader size is a sign of a good scaffold. Trunk taper at the base of the trunk helps support for the entire crown. Young trees with no trunk taper usually have to be staked, so they don't topple over in high winds or under heavy loads of ice and snow. Finally, branches that have a wide angle of attachment or have connective tissue in the crotch are usually more structurally sound than those with sharp angles of attachment or imbedded bark in the crotch.

Plant Stress

Trees, regardless of species or location, have the same basic needs that must be met for the tree to remain healthy and grow. Basic requirements for plant growth include water, carbon dioxide, oxygen, nutrients, sunlight, appropriate temperature, and sufficient space. A balance must be maintained between the amount of water lost through the leaves and that taken up through the roots. Soil conditions must allow enough root growth to supply the leaves and branches with nutrients, gaseous exchange, and water. Photosynthesis (the manufacture of sugar by the green parts in the presence of sunlight) must be able to supply the energy needs of the tree. And this energy must be conveyed from the leaves to the stem and roots.

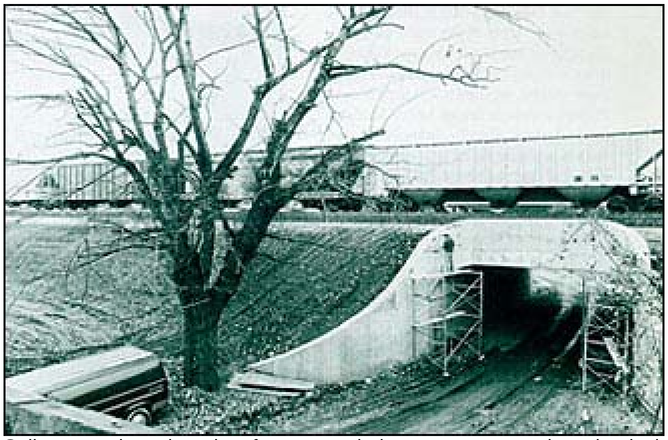
The trees planted in the median strip outside this row of fraternal houses near the University of Washington campus are suffering primarily from soil compaction associated with the recreational use of this space.

Last but not least, the strength with which the tree grows , known as vigor, must remain high enough to prevent attack by disease-causing agents, such as bacteria, fungi, and insects.

The urban environment often places tremendous stress on trees that natural defenses may not adequately protect against. The urban environment changes rapidly, at least in comparison to the life span of most trees. The amount of stress experienced by a tree is directly related to the rate of unfavorable change in its environment, the quality of the planting location, and the level of maintenance it receives. Noninfectious diseases, which are not transmittable from a diseased plant to a healthy plant, will be especially threatening to trees whose defenses are weakened by urban pressures. Most urban stresses can be divided into the broad categories of environmental stress, animal injury, and people pressure.

Most urban stresses can be divided into the broad categories of environmental stress, animal injury, and people pressure.

Environmental stress has the most severe effects on newly planted trees that have not yet adjusted to their new conditions and on established trees whose surroundings have changed, usually from the activities of people. Temperature stress results from extreme heat and cold as well as rapid changes. High light levels are usually associated with high temperatures. Thinning or clearing operations can expose remaining trees to excessive sunlight threatening them with light and temperature stress. Minimize the negative impacts of high temperature and light by planting shrubs and ground covers to create an "understory" beneath and around the trees. These new plants will help keep the area cooler. In areas surrounded by concrete or asphalt group the trees together or plant an understory to buffer high temperatures.



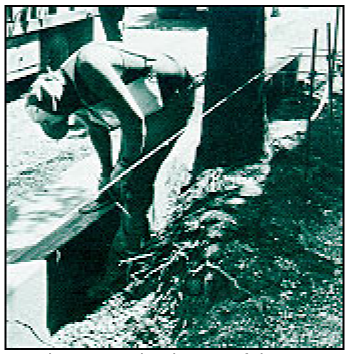
Soil compaction, altered surface water drainage patterns, and mechanical damage to this tree's roots are three stress factors represented at this freeway construction site

Low temperature can also injure trees. "Hardiness" refers to the adaptations of woody plants to cold conditions through patterns of growth and dormancy. While plants can often tolerate extreme cold during the dormant season, they could be injured by the same temperature during the growing season. Select plants with the extreme rather than the average temperature in mind. Plants in containers are more susceptible to extreme and rapidly changing temperatures, because their roots are not protected by the "thermal mass" of the earth.

Moisture stress is one of the most common problems. Too much or too little water both inhibit root function, and therefore, the growth of the entire plant. Physical damage from snow and ice, poor water quality, and erosion could also be classified as moisture stress.

One of the most important factors contributing to moisture deficiency is the amount of space available for the roots. If roots are restricted, they cannot spread through enough soil to gather the moisture needed to support the crown.

Another type of moisture stress occurs mostly in broadleaved and needled evergreens. During the winter animals --both pets and wildlife and spring, the air may be windy and warm, but the soil frozen or dry. Known as "winter drying" conditions, more water is lost through leaves than is taken up by the roots.



Road construction is one of the most damaging forms of tree stress in urban environments.

Excess water from flooding, saturated soils or over watering can also place stress on the tree. Like other parts of the tree, roots need to ex change gases, such as oxygen and carbon dioxide, in order to survive. This exchange of gases occurs between the fibrous roots and the air in the soil's large pores. If the pores are filled with water, the roots suffocate. To avoid problems with excess moisture, determine the soil moisture and drainage patterns of the planting site, select a tree that thrives under, or at least tolerates, those conditions, or modify the soil situation.

Soil stress can be classified as either chemical, biological, or physical. Chemical stress involves unfavorable pH, an imbalance in nutrients, or even the presence of toxic materials discharged into the soil by other plants or human recklessness. In cities, soil stress is usually related to physical changes affecting soil aeration and moisture. Physical stress involves something that restricts root growth, including streets, sidewalks, buildings, construction activities, construction debris in the soil, large boulders, trenching, grade changes, soil compaction, improperly used herbicides, and the roots of other trees.

Cultivation of wet soil leads to soil compaction and should be avoided.

Animals injure trees in several ways. Animal waste, especially urine, adds toxic compounds to the soil. Animal traffic compacts the soil. A host of animals --both pets and wildlife inflict direct injuries to the bark: birds peck it, cats shred it, and rodents chew it. Dogs are particularly destructive when chained to a tree.

People apply a variety of pressures that adversely affect the health of trees. Trees are easily disturbed by construction of buildings and roads, soil compaction, chemicals, air pollution, and improper tree maintenance also fall into this category.
In addition to the stresses that come from the direct or indirect actions of people, urban trees also suffer from human inaction. Well meaning people sometimes impede appropriate urban forest management. Education is one way to increase the knowledge of urban forestry and to get people to work together to support it.

Restricted root space is capable of causing roots to grow in a girdling pattern, creating a structural deficiency in the anchorage of the tree.

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Urban Forestry Planning

Planning is a method for achieving an end, a detailed formulation of a program of action, or an orderly arrangement of parts of an overall design or objective. Planning is the process of establishing goals, policies, and procedures for a social or economic unit. Some people believe the planning process culminates with the publication of a document that presents detailed instructions for reaching a goal, but it does not end there. The final result of planning is the attainment of the goals, not publication of the plan.

Planning for the infinite future could be a daunting task, so the process is generally divided into smaller components: long-range, short-range, and site-specific. Long-range planning tends to be extensive, broadly worded, and enforced through a legally adopted comprehensive plan. Often, these comprehensive plans are refined to specifically address development with regional impacts. Short-range planning, also known as current planning, tends to be explicit, and is enforced through zoning ordinances. Site specific land development regulations may overlap zoning ordinances.

Long-range Planning

Long-range planning mainly concerns growth management, and encompasses the preparing, maintaining, and updating of a comprehensive plan. State government establishes guidelines that must be met by comprehensive plans at the state, region, and county levels. Urban forestry concerns must be reflected in comprehensive planning. By adopting the plan, government officials signify their support for trees in the urban environment.

Comprehensive plans generally contain, among other things, elements that address the environment and transportation. Both of these elements should contain references to trees as they relate to the urban infrastructure. The environmental element should identify the need for preservation of the natural environment within developed areas. This element should also contain language calling for planting, maintenance, and preservation of native and introduced species along streets and in other open spaces. The transportation element should incorporate aesthetic considerations in the development of traffic circulation systems, and in providing for adequate right-of-way for tree planting.

Short-range Planning

These plans help achieve desirable land-use allocation and distribution based on an assessment of the cumulative impact to a given area. Short-range plans usually serve to refine comprehensive plans and development proposals. They are enforced through zoning ordinances. Supporters of urban forestry can use the short-range plans to document areas in need of special attention. This may include preservation of critical habitat, development of tree-lined corridors or beautification of major entrances to the community. Including these concerns in the short-range planning process helps solidify support from planning staff and local decision makers.

Site Specific Planning

Planning for a specific site also has several levels: conceptual, schematic, and master. Conceptual planning illustrates possible physical forms and relationships between various elements of the project. This phase may even be done before a site is selected. Schematic planning may develop several design alternatives for a specific site, but not in enough detail to implement them. Once a schematic design is selected, the master plan refines the design and adds details. Based on an approved master plan, designers produce development plans, which may be reviewed by building, zoning or transportation departments.

Site specific planning includes efforts concentrated on site plan review. Enforced through land development regulations, this level of planning affects preservation and planting of trees on particular sites. Significant individual trees or entire stands may be planted, saved or removed based on a plan at this level. So regardless of the contents of higher level plans, site specific plans should be scrutinized before approval is given. Before development, sites should be inspected to verify that plans have been drawn correctly and that tree protection measures comply with development regulations.

Management Planning

Then there are management plans, which define the overall scope and methodology of certain operations, such as urban forestry or transportation service.

Urban forestry management plans generally follow the planning process mentioned previously. They may also include: maintenance standards, tree inventories, work record processing, planting, removals, reforestation, rotation planting, phased removal, tree selection processes, design criteria, personnel training and development, budgets, coordination within an agency, as well as with other agencies and citizens.

Two specific types of management plans-tree inventory system planning and long-range tree rotation planning-deserve further description. These types of management plans are important because of their effect on the efficiency of urban forestry operations, their impact on budget justifications, and the potential for conflict within the community.

Tree inventory system planning is a method for obtaining and organizing information about the number, condition, and distribution of urban trees. Information that is accurate, accessible, and simple is one of the best tools for making planning and management decisions. With tree inventory information, program resources can be allocated appropriately among the various tree management functions, work can be scheduled for maximum efficiency, and financial decision-makers can evaluate various work plan proposals by comparing expected results with projected budgets.

Several inventory systems have been developed by cities, universities, extension services, and consulting firms. They range from quick, inexpensive survey methods that provide basic information to sophisticated, computerized systems that are integrated with daily tree care activities. *A Guide to Urban Tree Inventory* Systems was developed by the School of Forest Resources at Pennsylvania State University in 1979. It contains a general review of the characteristics of urban tree inventory systems, as well as profiles of 25 systems and references to 24 other inventories.

All inventories share the same general goal-to provide information about the nature of the urban forest. Most inventories have several objectives. The simplest systems might provide information to support the establishment of a tree care budget, start a community tree program, or at least, initiate a tree advisory board. At this level, the desired information may be as simple as three estimates: the total number of trees, their average condition, and their monetary value.

Computerized systems may be used to justify and prepare annual budgets, organize daily work assignments, keep records on individual trees, aid long-range planning, and support management analyses. These types of inventory systems link day-to-day operations with long-range planning.

Long-range tree replacement or rotation plans should be based on inventory information. Because tree removal or replacement generates community concern, citizens and policy makers should both be involved in the process.

The basic elements of a rotation plan

— Criteria for tree removal;
— Complete versus phased removal;
— Diversity versus monoculture in replacement species;
— Management plan for replacement activities; and
— Fiscal budget.

Criteria for tree removal form the basis for objectivity in the midst of the emotional furor that often develops over tree removal in urban areas. Objective criteria would include: current and future maintenance costs, years of estimated useful life, structural integrity, and public welfare. Because they are more subjective, the following items should be considered only as secondary criteria: diminishing aesthetics, amenities, and engineering values, such as noise abatement and wind reduction.

Removal recommendations must clearly identify priorities for tree removal. These priorities could become a sequence for removal. Dead or dying trees might be first. Second would be trees representing a potential hazard to adjacent property, buildings, parked cars or people. Next might be stumps from trees cut previously. The final category could be trees growing in undesirable locations.

Complete versus phased removal is one important decision that must be made before a management plan for tree removal is developed. Complete removal, as the name suggests, is the removal of all trees within a given area in one operation. In phased removal, a predetermined portion of a stand is removed on a schedule covering a period of years. Where space allows, new trees can be planted among existing ones that have been scheduled for removal. This approach, known as interplanting, encourages age diversity in the stand and minimizes aesthetic and environmental impacts of large-scale tree removal. Interplanting copies nature by providing new trees to take over before older trees come down.

Diversity or monoculture in tree species replacement will usually be an issue in most communities. Species diversity stabilizes the urban forest and tends to reduce losses due to harmful insects or disease. While having similar maintenance requirements is a primary consideration in species selection, large-scale monocultures should be avoided. Diversity also offers the adjacent property owners some individuality. Again, citizen involvement is valuable in developing the rotation plan.

Management planning for replacement trees must ensure the long-range maintenance for these replacement trees. Young trees require considerable care, such as watering, fertilizing, insect and disease control, and regularly scheduled pruning. Any plan must ensure long-range maintenance to protect the investment of public funds in replanting. For example, scheduled trimming of young trees reduces the need for expensive corrective pruning of mature trees.

Budget and long-range funding for tree replacement is an obvious element of the basic rotation plan. Many of the criteria mentioned previously will provide meaningful budget information. Cost/benefit approaches are helpful in justifying tree rotation plans, because policy makers often reduce programs to dollars and cents.

Work Plans

Work plans fill in the details by guiding operations through specific periods of time (from several months to several years) and through specific locations (from a park to a watershed). Because on-going projects need funds, allocated budgets are an essential element of work plans. Because work plans generally address active projects, they change periodically as the projects change. Work plans might address specific planting projects, new tree care, care of established trees or implementation of a tree inventory.

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Tree Selection and Site Design

During this century, the form and character of cities and towns have changed dramatically. Fifty to one hundred years ago urban areas were different; cities were smaller and skylines rarely rose above eight to ten stories. Automobiles were not the major method of personal transportation, and the ratio of open space to buildings was dramatically different. Even the lifestyles of urban residents have changed.

Urban Change

Cities are dynamic, with ever-changing land uses. This is particularly true today. In planning the urban forest, it must be assumed that cities and towns will continue to change. The likelihood of changes and the character of potential environments should be carefully considered. Tree selection must assume that the urban forest will be dynamic, if it is to respond to the changing conditions of the community.

Space for Trees

The stereotypical image of the "city" as a place of continuous tall buildings and intensive, pedestrian - oriented streets is accurate for only a small percentage of urban areas. Most urban environments consist of automobile oriented, low density land uses and recently constructed buildings.

Cities are actually more spread out than the stereotype suggests, with a higher proportion of open space to buildings. However, the presence of open space does not necessarily imply more room for the urban forest. The majority of open space is devoted to transportation corridors and car storage. Space is almost always a limiting factor in some way. It could be a conflict between vehicles, pedestrians and trees for space at ground level. Above ground, the canopies of trees interfere with overhead utilities and views. Beneath the ground, tree roots compete with utilities and paving.

In urban environments, natural areas with continuous vegetation are replaced by discontinuous and fragmented vegetation. The space available for trees occurs in small pieces rather than large ones. In some areas, such as downtown cores, fragmentation of planting sites is extreme. Greater continuity can be found in residential neighborhoods, stream corridors, steep slopes or around other extensive land forms.

There appears to be a trend toward increasing density in many new residential and commercial developments. This threatens a corresponding reduction in the space available for trees.

Climate And Microclimate

Environmental conditions tend to be more varied in urban areas than in less developed areas. For example, asphalt surfaces surrounding one site make it hot and dry. But around the corner, buildings cast shadows that cut temperatures and minimize evaporation of soil moisture. Light, wind, temperature, and soil conditions can change abruptly from one spot to another.

Urban conditions are frequently more severe for the growth of plants than in natural environments. On the other hand, conditions could also be better due to irrigation or lack of competition.

Seasonal variation may also be extreme compared to more natural areas. A site may be hotter in the summer and colder in the winter. Or, it may be drier in the summer and wetter in the winter due to soil compaction and the presence of paved surfaces. However, the city as a whole generates heat that usually keeps temperatures warmer in all seasons than more natural areas. This is called the "urban heat island" effect.

While it's not possible to generalize about the severity of urban conditions, one thing is certain. Conditions vary considerably, and it's wise to assess each site individually. The best way to identify site conditions is to tour on foot. Be sure to consider changes that are planned in the vicinity, even if plans are not yet final. The construction of streets and buildings, rechanneling surface water, and routing utility corridors can all affect the ability of a site to provide for the needs of trees. While it's best to anticipate urban evolution, it's safe to assume that plants and people will always have to adapt to unforeseen changes.

Land Use
One goal of urban forest management is to create and maintain the maximum amount of visual and biological diversity. Preserving the uniqueness of different areas involves selecting trees that compliment the activities occurring there. This may require drawing on a broad range of plant species to create a distinct character. The urban landscape can be divided into four broad land use categories: natural areas, parklands and campuses, residential property, and fragmented spaces. These categories are based primarily on activities that take place in them and the mood created by those activities.

Natural areas are relatively undisturbed. The typical urban resident also considers them to be "natural," because of their size and location. These areas tend to occupy land considered unbuildable due to poor accessibility, rugged topography, poor soil, or inappropriate hydrology. They are frequently linear, such as ravines, stream corridors and steep slopes. Other types of natural area in this category may include: "greenbelts," flood plains, wetlands, ponds, waste areas, abandoned land and "buffer zones" around undesirable land uses, such as land fills.

Activities occurring in natural areas range from casual recreation to no activity at all. Increasingly, these areas are seen as valuable components of the urban environment, because of their aesthetic qualities, their symbolic value as reminders of the natural environment and their value as critical natural habitat.

Coherent management policies for these types of areas have rarely been developed. They typically receive little or no maintenance, and are left to their own devices. They have almost always been disturbed by human activities at some point in their history. In most cases, these areas are in some stage of plant succession as wild plants and animals re-establish themselves. For these areas, select native trees that enhance or maintain the feeling of a "natural" environment by preserving an "uncontrolled" appearance.

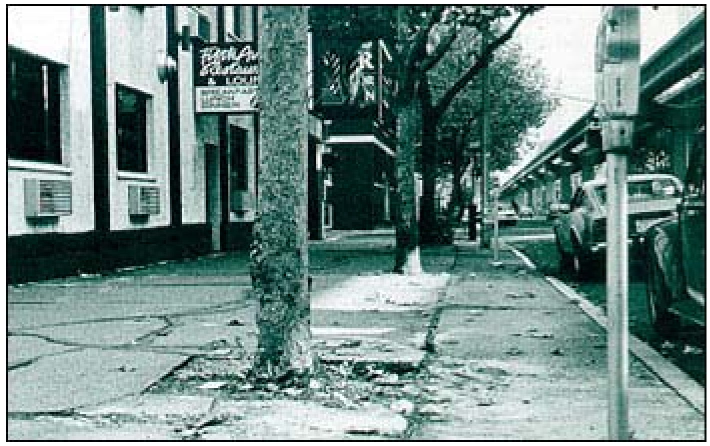
Parklands and campuses
include traditional parks that host recreational activities, community open space in planned residential developments, freeway interchanges, as well as business and industrial parks with a campus-like atmosphere. These developments are normally large, with a high percentage of open space to paved or built-up areas. They typically contain large lawns and clearly defined beds of flowers or shrubs. Trees are planted as individuals, groves or small woodlands. Although they usually receive relatively high levels of maintenance, some people consider their character to be "natural." This feeling may grow from traditional landscape maintenance techniques and "naturalistic" plant arrangements.

These areas are intensively used. Even as a campus of industrial or commercial buildings, the landscape may simply be an area viewed by workers and visitors-but rarely entered. If it is only looking out an office window, these people are using the outdoor areas and benefitting from the presence of well-maintained trees and lawns. So, observation represents a high level of "use."

Attitudes toward these areas may be changing, prompting a change of management. Measures are sometimes taken to reduce maintenance costs, encourage wildlife habitat or allow for a wider variety of uses to occur within these campus areas. The long term implications of these trends must be considered when trees are selected.

Residential land
comprises a very large portion of most urban environments. In these areas small parcels are typically under the private ownership of different people. Several issues grow out of this pattern of

ownership.



Buildings divide the open space into small, tight fragments. The visual character and the level of maintenance varies dramatically from properties with a relatively "natural" appearance to those that are manicured and open. The intensity of uses include passive visual appreciation, active recreation and even storage of personal possessions. There may not be a consistent pattern of open space. In some cases, buildings and paved surfaces occupy most of a lot, while on others, they cover only a small portion of the total area.

Because of the diversity found in residential areas, planting guidelines should be general rather than specific.

Streets, plazas, and fragmented planting areas have the greatest variety of physical conditions. They range from the narrow, canyon-like streets of the urban core to wide open areas around suburban streets. Between these extremes are streets and boulevards in residential, industrial or commercial areas. Fragmented open space includes parking lot islands and narrow planting strips around parking lots or next to buildings. Fragmented areas and streets fall into the same category, because plant selection criteria and environmental conditions are similar.

In these areas, available space is restricted and the land is divided into small pieces. Urban rooftop gardens where plants must be grown in containers offers an extreme example.

When selecting plants for this component of the urban forest, remember that it is essentially a symbolic forest it is also the most visible part of the urban forest, and the largest part in public ownership. Rather than designing a natural forest, the urban tree manager chooses plants that will bear the burden of this symbolism under the most stressful of the urban environments.

Tree Selection Considerations

One of the Most important aspects of urban forestry is selecting and acquiring trees. As stewards of the urban forest, today's tree planters have an obligation to contribute the best possible trees to future generations.

Tree selection and acquisition are also among the most challenging activities of urban foresters. Thousands of species are available, many of them genetic hybrids that have not been tested by time. Few people know all of the species. Objective information on long-term maintenance requirements and other potential problems is not readily available. In the absence of hard data, some tree managers assume that maintenance needs correlate directly to the rate of growth. In other words, a fast growing species will require more long-term maintenance than species with moderate or slow rates of growth. It may also be reasonable to assume that larger trees require greater expense for maintenance and replacement. With proper care, a tree could live for centuries. It makes little sense to ignore known shortcomings, simply because the problems will become apparent only when the tree matures.

Although it may be tempting to choose species that appear frequently in the landscape, popularity should not determine suitability for urban uses. Many desirable trees that require minimal maintenance seldom find their way into the urban landscape and may not be available from nurseries. Finding the best species requires research. Nursery catalogs are one source of information. The book, *Plants that Merit Attention, Volume 1,* Trees, may be useful for identifying nursery sources for a selected group of species. It was prepared by the Horticulture Committee of the Garden Clubs of America, edited by Janet M. Poor and published in 1984 by Timber Press.

Picking the best tree species for a particular site is similar to separating gold ore from the surrounding rock. Beginning with an extensive list of trees, the forester must sift out unwanted material until only the right choice remains. To be selected, trees must pass through three levels of selection similar to a series of sieves. These considerations can be grouped into three categories: site, design, and maintenance.

Site Considerations - The environment that will support trees encompasses space, moisture, soil, and other physical conditions. As mentioned earlier, the environment is affected greatly by the land use of a particular area.

Space could limit growth now or in the future. Consider the way that a particular tree will interact with the surroundings. Remember that trees occupy space above the ground, at ground level, and below ground.

The tree canopy offers the most immediate and visible concern. Most people would like to see a tree fill the space available. However, canopies that grow too large will require heavy pruning and possibly removal. Crowns in streetscapes could interfere with adjacent buildings, overhead utility lines, and views. Trees could also shade devices designed to capture solar energy or gardens that need ample sunlight.

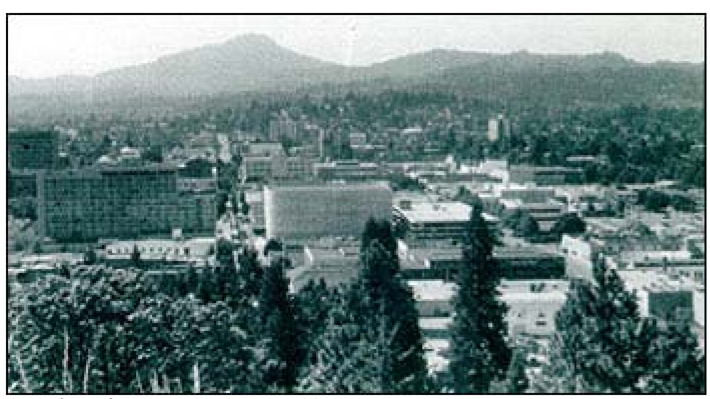
Ground level refers to the space that begins at the soil surface and extends up to fourteen feet above the ground. Some areas require no clearance at ground level; sidewalks need ten feet for pedestrians; and streets need fourteen feet. Selecting trees with these requirements in mind can prevent unnecessary pruning later.

The space available below ground could be restricted by utility lines, building easements, vertical retaining walls or heavily compacted soils. Considering the way that trees fill space helps to choose a tree that will fit the site when mature.

Climate may vary from one site to another. Sunlight, wind, moisture, air quality, and temperature extremes all influence the choice of tree species. The conditions in an urban park are similar to those in undeveloped areas. But cities also have concrete canyons with low levels of sunlight, and the urban equivalent of deserts-large paved areas with intense sunlight, high temperatures, and little moisture.

Soil conditions must be assessed to identify fertility, aeration and drainage. Matching these site factors to the needs of potential tree materials is critical to the success of any planting.

Design Considerations - Various elements in the landscape relate to each other on an aesthetic level as we] I as a physical level. Trees can be selected for the way their size, shape and color blends-or contrasts-with other elements. Trees may be selected for their texture or fragrance. The timing of leaf set and drop or the schedule of flowering may be important. The type of shade or the density of the crown could also affect the choice.


Overview of Eugene, Oregon, 1988.

A tree's above-ground branching system-or crown-determines the overall shape. Some tree shapes are more suitable than others for particular sites. And, shape affects the amount of volume that the tree will occupy. Common tree shapes include: oval, round, columnar, pyramidal, and vase.

Oval trees fit nicely into most street plantings, because they grow upward and don't interfere too much with adjacent vehicular traffic. Because of their somewhat upright growth habit, oval trees can generally be placed closer to buildings than more spreading trees. But, oval shaped trees may reach a lofty height, making them unsuitable for planting underneath power lines.

Round trees have a spreading growth habit, resulting from more than one terminal leader. Lateral branches growing from the leaders may ascend, extend horizontally or sweep downward. Trees with an ascending branch structure are more compatible with city streets where there are buildings nearby or large trucks that must pass underneath. Trees with a descending branch pattern may require more pruning while the tree is small to maintain visual or vehicular clearance. However, once they grow larger, downward sweeping branches are valued for the sense of enclosure they suggest. A horizontal branching structure demands a greater distance between adjacent trees or buildings, if it is to attain a natural form and require minimal pruning.

Columnar trees usually have tightly ascending branches with narrow branch angles and short branches. Trees with this shape are valued for their narrow width that enables them to be planted in tight spaces where there is not enough room for a tree with a spreading branch structure.

Pyramidal trees often start off as columnar. With age, the lower branches get bigger and droop under their own weight. Many trees in this category have a single dominant branch from which the side branches grow. While conifer trees, such as pines, best illustrate the pyramidal shape, there are also many broadleaf trees in this category.

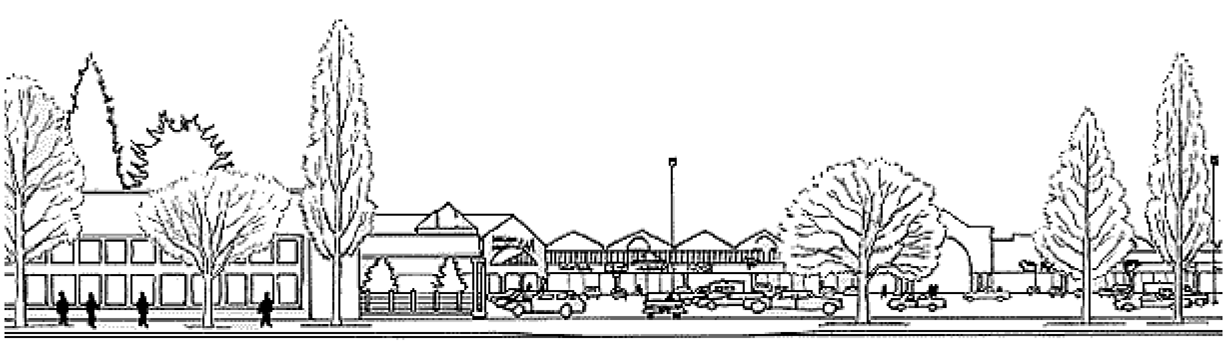
Vase shaped trees may be the most appropriate for planting on city street trees, because they grow up and out. They also arch over streets and sidewalks to form a shady canopy, while maintaining visual clearance and vehicular access.

Design requirements usually grow from site characteristics. For example, street trees typically need clear trunks. They grow as individual specimens, widely spaced in streets, without competition from adjacent trees until nearly mature. By contrast, trees for parks often grow in large groups. Early in their lives, they protect each other. But long before reaching their mature size, they begin to compete.

Nurseries now offer a wide selection of crown shapes, especially from clones. For example, the red maple clones (Acer rubrum) range from the narrow upright Armstrong to the widespreading, rounded Schlesinger. Similar variation can be found in the Callery pear (Pyrus calleryana) and Norway maple (Acer platanoides) groups. This diversity of crown forms allows for more precise matching of trees to site conditions.

While clones are genetically predisposed to uniform growth, they do not guarantee uniform performance in the landscape. Site conditions vary considerably over relatively small distances. A series of clonal trees placed along a street could encounter a variety of site conditions that could affect tree performance and appearance.

Shoot development, or crown configuration, also affects the success of urban tree plantings. The development of a multi-trunked character, the height of the first branches and the presence of poor branch attachments may adversely impact the vigor of a tree, or require more intensive management to make the tree compatible with adjacent land uses.



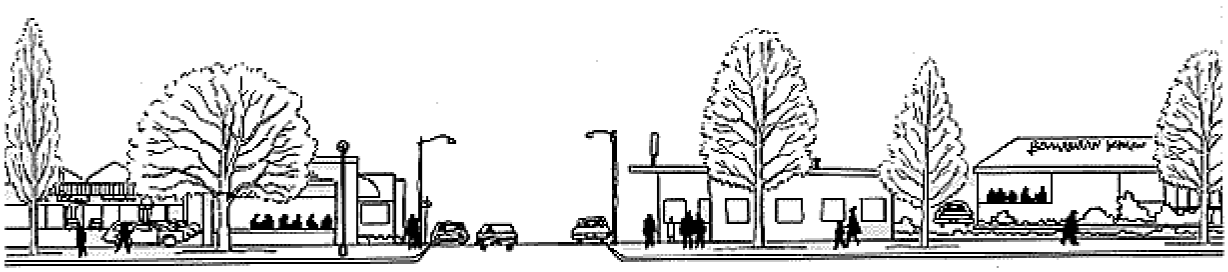


Figure 3. The "Unfolding Urban Landscape" with trees of different shapes: oval, round, columnar, pyramidal, and vase-shaped. *Illustration by Ann Christensen*.

Maintenance considerations - Maintenance will re required of all tree species, but some will require far more than others. Given limited budgets, it makes sense to give maintenance requirements a relatively high priority among selection criteria. Pruning needs, fertilizer, water and pest management, and root control should all be anticipated.

Cities have long faced the problem of roots breaking sidewalks. Many people have searched for "deeprooted" species. However, the depth of rooting is more a function of site conditions, than an inherent characteristic of a species. Actually, most species are regarded as having shallow roots at maturity. Even so-called "taprooted" trees possess their vertically oriented roots for a short period of their lives. To reduce the importance of sidewalk damage as a criterion, use appropriately sized trees for the given space and planting techniques, such as large pits, root barriers, or deep planting.

Tolerance of stressful conditions is an important criterion for tree selection, and every site offers some type of stress. Generally, successful street tree species tolerate poor soil conditions, including fine texture and flooding. Tolerance to polluted soil may be needed. If salt is commonly used to clear the icy sidewalks, trees with a tolerance of salt should be selected. if the site has been disturbed, the pH level may influence the choice of plants.

Naturally, a species' susceptibility to harmful insects and disease should be considered, along with the cost of controlling them. For example, autumnal is flowering cherry (Prunus subhirtella) occurs widely, even though this genus is vulnerable to one of the most common diseases in the area: brown rot. Controlling brown rot requires an expensive multi-spray program. So, planting this species brings with it the burden of an intensive pest management effort.

Poor branch attachments, such as those with embedded bark, narrow angles of divergence or poorly spaced branches, become a major maintenance problem as trees mature. Some of these problems can be corrected at planting. Others can be eliminated by rejecting poorly structured trees from the nursery at planting.

Not every tree or every planting situation lasts for hundreds of years. Being dynamic, cities have spaces that are available for relatively short periods, making them suitable for short-lived trees or those that begin exhibiting undesirable traits as they mature. For example, big leaf maple (Acer macrophyllum) grows rapidly for 40-60 years. Then, branches begin to break out of the crown, and pruning requirements increase. In a similar manner, western white pine (Pinus monticola) reaches 60 to 80 feet in height after only 40 or 50 years. At this age and size, the trees become susceptible to white pine blister rust, which is always fatal. In situations where a tree is only needed for fifty years, both species would be excellent choices. While they develop problems as they grow older, in youth they offer a number of positive ornamental and management features.

Depending on the site, species' ability to withstand drought, freezing, wind, and air pollution should also be considered.

Urban areas offer a mosaic of environments and design possibilities, so there is tremendous opportunity to use a large range of trees in the urban forest. With such a great number of environments and design considerations, an equally large number of plants may be appropriate for use. This diversity reinforces the need for thorough site analysis and careful design for every project.

Providing Space For Trees In New Construction

Space for trees is readily available in open spaces around homes, in public parks, and school grounds. But in parking lots and along streets, adequate space for trees may only be available if it was specifically included during the design of the overall development.

During hot weather, parking lots can be as forbidding as great deserts. With proper planning, trees can minimize the heat. Spaces for trees should be scattered throughout the paved area, rather than only along the perimeter. These planting strips should be large enough to accommodate trees that will eventually grow large canopies and shade the parked cars. Areas surrounded with pavement should allow a square area at least six feet on a side. And, an area eight feet square would do much to prevent tree roots from eventually becoming a problem. Governmental bodies that regulate shopping center developments can require that the parking lots contain ample space for trees as well as for cars.

Street trees comprise about 85 percent of publicly-owned urban forests. They occupy an important and often overlooked-public land base. These unpaved ribbons along streets are commonly known as planting strips, parkways, or treelawns. Minimum widths identified by municipal codes are often inadequate for supporting mature trees, and some codes fail to mention trees at all. Since the size of existing street rights-of-way have remained the same for centuries, only future rights-of-way offer hope for adequate treelawns.

There are two practical ways to design treelawns of more appropriate location and width. The first approach combines the sidewalk and the curb as a single unit (monolithic design), so the treelawn occurs between the sidewalk and the right-of-way boundary. Called a **boundary treelawn,** it has been used widely on the West Coast since the middle of this century. The tree can be located off-center near the right-of-way boundary relatively far away from the sidewalk.

The more traditional arrangement, called a **curbside treelawn,** is located between the curb and the sidewalk. Besides using this space for street trees, curbside treelawns serve as storage for snow plowed from the street. Usually wide street rights-of-way make extra-wide curbside treelawns possible.

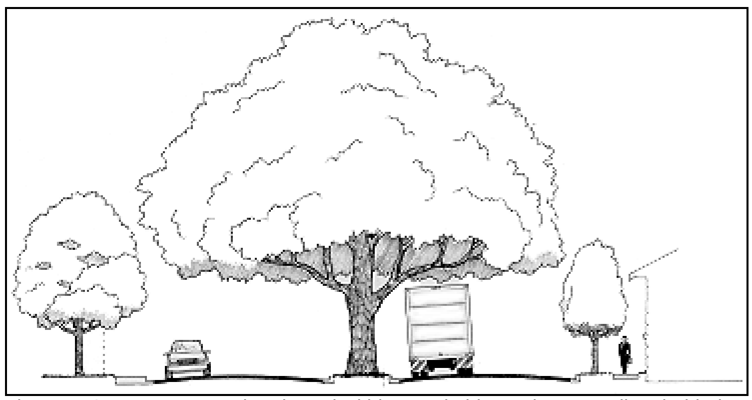


Figure 4. Street trees may be planted within a curbside treelawn, median, behind the curbside sidewalk in the boundary treelawn, or outside the right-of-way, on private property.

No standards exist for the width of treelawns. Prudence suggests that treelawns should be made extra-wide to accommodate large trees that will form a canopy over the streets. Wide treelawns also reduces the chance that roots will damage sidewalks. Preventing treelawns from cutting into the amount of land available for building is simply a matter of shortening the building setback.

Boundary treelawns make good use of space. For example, a tree planted one-half foot from the right-of-way boundary would be three and one-half feet from the sidewalk. While greater distance between trees and sidewalks may be better, three and one-half feet is reasonable. Since trees customarily grow midway between curb and sidewalk, achieving the same amount of space between trees and concrete in a curbside treelawn would require seven feet.

To implement any of the these concepts, a local government may have to amend its regulations concerning location of the treelawn, width of the right-of-way, and distance of the building setback.

Designing for Root Control

Tree roots are notorious for buckling the pavement of sidewalks and streets. Uneven surfaces may pose a hazard to pedestrians and motorists. Researchers are looking into several methods of preventing, or at least delaying, this type of damage. Planting time offers the best opportunity to prevent conflict between trees and pavement. Here are some techniques that may minimize the damage:

— Select species that best fit the available space (Fig. 5).

— Obtain trees produced on rootstocks with inherently deeper growth.

— Choose trees with columnar root balls.
— Install planting hole liners, deflection barriers (Fig. 6), pervious barriers, and chemicals barriers, to inhibit shallow root development.

Deflection barriers may be plastic sheeting that diverts roots away from a paved surface. Properly designed underground planters or planting hole liners can also block lateral growth, and force roots deeper. Pervious barriers could be fashioned from loosely woven plastic fabric or geotextile situated in the soil to prevent roots from penetrating into areas where they would cause damage. Chemical barriers, such as copper screen or geotextile impregnated with herbicide, inhibit growth in the tips of roots as they grow near the barrier.

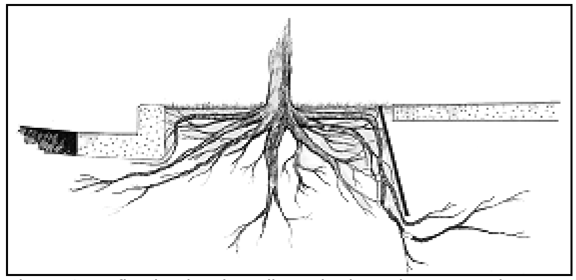


Figure 6. Deflection barriers direct the lateral root growth.

Researchers are testing these methods individually and in various combinations. Until proven strategies emerge, it is prudent to simply allow ample space for root growth, and where that is not possible, plant smaller trees.

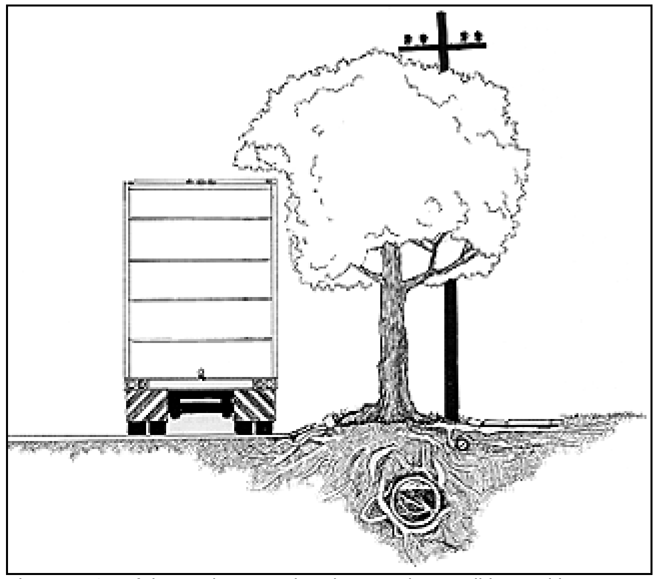


Figure 5. Careful attention must be given to site conditions, either existing or proposed, when selecting the trees to be planted.

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Planting and Early Care

Handling Before Planting

Trees should be carefully inspected at the nursery or upon delivery to be sure they meet specifications for species, root quality, top conformation, and health. They may need to be acclimatized to their new site, a process known as hardening off. Both roots and tops must be kept moist and protected from temperature extremes.

It is best to plant bare-root deciduous trees and shrubs soon after being received. However, they can be held for a few weeks, if kept cool so neither roots nor buds become active. Balled-and-burlapped (B&B) and container grown trees can be planted almost any time, although it is wise to plant B&B plants soon after they are dug. Root balls and containers should be protected from the sun so that periphery roots are not injured.

Preparing the Planting Hole

In most soils, dig the planting hole one to two inches shallower than the depth of the root ball. In sandy soils, the hole can be as deep, or almost as deep, as the root ball. To prevent settling, make sure that the bottom of the hole is firm. The base of the trunk should be high enough to set slightly above the soil and to prevent water from collecting around it after rain or irrigation.

The hole should be about twice the diameter of the root ball, so backfill soil can be placed easily. For bare-root trees, the hole only needs to be large enough to take the roots without crowding. Roughen the sides and bottom of the hole with a shovel to enhance root penetration into the surrounding soil.

Preparing and Setting the Tree

Prune back the dead, diseased, broken, and twisted roots of bare-root plants to healthy tissue. For container grown plants, remove most of the roots that are matted at the bottom or are circling around the root ball.

Straighten the remaining ones. Roughen the outside of the root ball to improve contact with the fill soil. A number of factors affect how a tree should rest in the hole. Since some of these may conflict with one another, priorities will be needed. Set the plant so that it will be viewed to best advantage. Place the crook of the scion of budded (grafted) trees toward the afternoon sun to minimize bark injury. If this is not possible, shade the area or paint it with white exterior latex paint. Orient the side with low branches away from the areas of high activity. Point the side with the most branches into the direction of prevailing winds.

If none of the above are problems, orient the plant with the largest branch or most branches away from the afternoon sun. The less developed side will benefit from more sunlight. For greatest stability of bare-root trees, place the largest root in the direction away from prevailing winds. If the top of the tree is not vertical when the root ball or trunk base is straight, tip the root ball to bring the trunk more upright.

Backfilling

Backfill the hole with the original soil, unless it is in extremely poor physical condition. Amending backfill soil with organic or inorganic materials has seldom proven to be of physical benefit even during the first years. Backfill amendments may contain nutrients or organisms that are beneficial to a newly planted tree, but amending the backfill is not the easiest or cheapest way to obtain such benefits.

If backfill is amended, the final mix should be at least 40 to 50 percent amendment by volume and mixed thoroughly with the soil. Sand should not be used as an amendment, and fertilizer should not be added to the backfill or placed in the planting hole.

Set the roots or root ball on a firm base. Before putting the root ball of a B&B plant in the soil, cut the fabric covering in several places to make it easier for roots to penetrate. Work the soil in among the roots of bare-root and container plants so their roots are not compressed into a tight mass, but are spreading and supported by the soil. After adding each three to four inches of soil, firm it gently with one foot. Before adding the last layer of fill soil to a B&B plant, cut off any loose fabric that would remain exposed above the ball. Gently fold it down and cover it with the last layer of fill soil. Exposed fabric can act as a wick and dry the root ball. Do not cover the rootball with backfill soil, it could keep water from wetting the root ball.

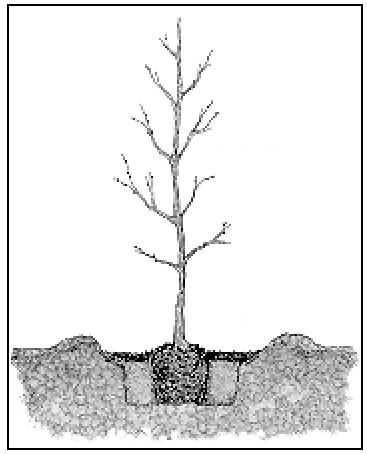


Figure 7. Planting detail.

Form a low berm around the edge of the planting hole and a higher one a foot farther out (Fig. 7). Water the inner basin to be sure the soil is moist and to help it settle. Double check the planting depth. If the original soil is at or below the fill soil, raise the tree. Gently lift bareroot trees by the trunk. Support B&B and container plants from below the root ball with a shovel while lifting gently on the trunk. Raise the tree two to three inches higher than finally wanted to allow for settling. Water the outer basin if the soil appears to be dry.

Staking and Guying

Trees that cannot stand upright on their own need to be braced with tall stakes or guy wires. Many nursery trees-particularly those in containers-are grown close together, tied to a single stake, and have their lower branches removed. As a result, they are unable to stand without support. The trunks of some trees are so spindly that they would bend below guys; these must be supported by stakes. if staking or guying is necessary, install the stakes or guys after planting but before watering the outer basin.

Two support stakes with one flexible tie near the top of each will hold a tree upright, provide flexibility, and minimize trunk injury and deformation (Fig. 9). Support stakes should be a little higher than needed to hold a tree upright in calm weather and allow the trunk to return to vertical after being deflected by hand or wind. Tie material should contact the trunk with a broad, smooth surface and have enough elasticity to minimize trunk abrasion and prevent girdling. Although widely used, wire inserted through hose can cause injury in windy areas. Support staking is temporary and should be removed soon after a tree can stand alone.

Most young trees that are exposed to moderate wind and weather concentrate their energy on growing strong enough to remain upright. They develop sturdy trunks that are tapered to bend without breaking, and strong root systems to hold trunks upright. It is wise to select such trees and to provide them with as much flexibility as possible when planted. Inspect stakes, ties, and the general condition of newly planted trees several times during the growing season to ensure tree health and well being.

If wind is not a problem, place the stakes in a way that provides maximum protection from traffic and equipment. In situations with moderate to strong winds, an imaginary line drawn between the support stakes should form a right angle to the most critical wind direction. The ability of stakes to withstand wind, particularly when the soil is wet, can be increased by connecting the two stakes with a wood cross tie partially or entirely below the soil surface (Fig. 9). Place the cross tie to the lee (downwind) of the stakes, being careful not to injure roots near the surface. If a single stake is used, it should be placed on the windward side of the tree to minimize trunk injury.

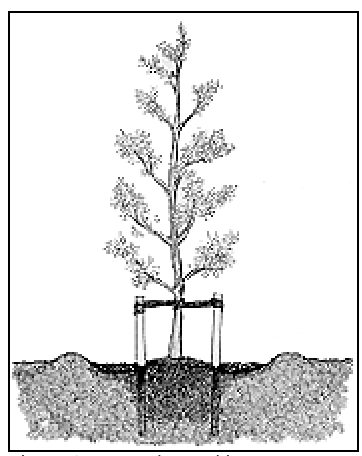


Figure 8. Protective staking.

Avoid placing a tie on the trunk closer than 30 inches from the tip, especially on trees not previously staked. This arrangement will subject the trunk to maximum stress at the tie and increase the chances of it being deformed or broken by the wind. A flexible auxiliary stake of light spring steel or bamboo may be needed to support the trunk terminal. In a densely-headed tree, thinning out some of the branches will lighten the top and reduce its resistance to the wind.

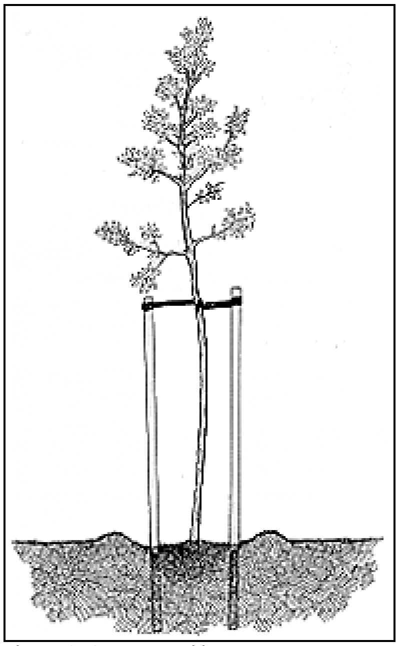


Figure 9. Support staking.

Young trees are particularly subject to vandalism, and few staking devices have successfully prevented damage. Many agencies plant larger trees to reduce tree damage. Planting trees with fairly dense skirts of small twigs along the lower trunk obscures vulnerable trunks. Seattle has been fairly successful in protecting young trees in vandalism-prone areas by using five-eights-inch thick metal reinforcing bar ("rebar") driven four to five feet into the soil and extending five to six feet above ground. A two and one-half-inch or larger diameter tree is tied at three heights to the stake. The stake is removed after one year.

Even trees that can stand without support need protection from equipment operations and other activities. To protect the trunks, set two or three short stakes just outside the root ball with 18 to 24 inches exposed. Other trees may be poorly anchored by their roots, although the trunks seem sturdy enough to hold their tops upright. Anchor these trees by guying their trunks or tying their trunks to stakes similar in height to protective stakes (Fig. 8).

Pruning and Training

In years past, severe pruning after planting was thought to be necessary. However, newly planted trees grow quite well if their tops are pruned lightly or not at all. On the other hand, up to 25 percent of the tops of newly planted trees can be removed without greatly affecting total future growth.

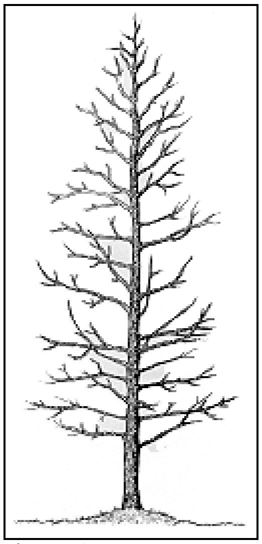


Figure 10.

The key to pruning is to encourage the growth of several large permanent branches, called "scaffold branches," that will ultimately form the basic structure of the mature tree. At planting, remove branches growing close to potential scaffold branches, crossing one another, damaged, and those having included bark in their attachments. Also, remove or reduce the size of large branches that are too low.

Central-leader trees, conifers, and some hardwoods, require little pruning to grow strong and well shaped (Fig. 10). However, species that become round headed may need considerable pruning the first few years to ensure the desired height of branching and strong branch structure.

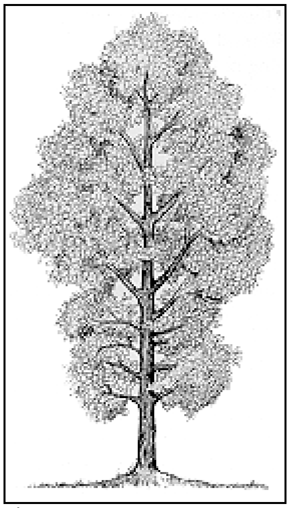


Figure 11.

During a tree's early years, frequent observation and directional pruning will guide the growth along a desirable course. This will improve the appearance and structural strength of the mature tree, and can greatly reduce the need for severe corrective pruning later. To do this, retard or remove large branches where they will not be wanted when the tree is mature. Temporary branches can protect the trunk from sun and vandals, as well as increase trunk growth and taper. Maintain temporary branches by encouraging twigs or keeping small branches cut back along the trunk below large permanent branches (Fig. 11). They should be kept small, and removed as the tree matures. This practice is in line with the observation that a tree is better able to withstand wind, snow, and ice if at least one-half of its foliage originates from branches along the lower two-thirds of the trunk.

The less a branch or tree is pruned the more total growth it will make. So, pruning should be used to control growth. For example, large branches that might be too low or that might compete or interfere with more desirable branches need to be pruned back or removed. Branches that will become the main scaffolds, particularly of large-growing trees, should be at least one-third smaller in diameter than the trunk where they arise, and should be vertically spaced at least 18 inches apart along the trunk (Fig. H5).

If a branch is in a desirable location but is large compared to the trunk or other branches, it can be pruned to reduce its leaf area and slow its growth. This increases the strength of the branch attachment, because the trunk can grow around the branch and hold it more securely. The relative sizes of a branch and the trunk are more important than the angle of attachment in determining the strength of that attachment, although a sharp angle of attachment is a good indication that branch size may be a problem.

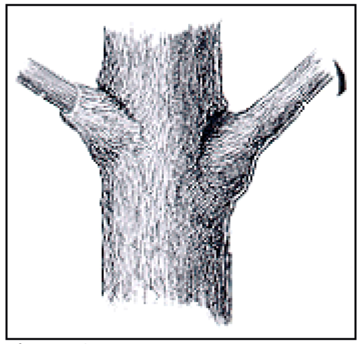


Figure 12.

A tree will be more open and retain its natural form, if branches are removed completely (thinned) in contrast to being headed or stubbed back (Fig. 13). Heading concentrates subsequent growth just below the pruning cut and results in dense foliage with weakly attached branches.

When removing a branch, make the final cut just outside the branch bark ridge in the crotch and the collar below (Fig. 12). This type of cut minimizes the size of a wound and the possibility that the trunk will decay. Painting pruning wounds has not been shown to reduce decay, and may even increase it.

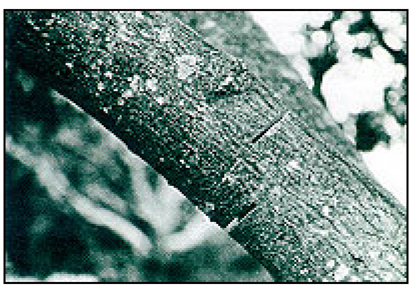
Fertilization

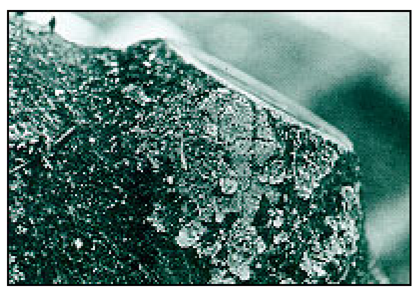
In some tests, newly-planted trees have responded to fertilization following planting, and in others response occurred only the year after fertilizing. Unless experience indicates otherwise, fertilization after planting is recommended. The benefits may be well worth the modest cost.

In most soils, nitrogen is deficient and the only added nutrient to which trees will respond. Nitrogen fertilizers are or become water soluble, so they can be applied on the surface and be carried into the soil with water.

After the first application, apply fertilizer in the late summer or fall, so it is available for spring growth. Water after fertilization being careful not to wash the material to the bottom of the watering basin. This could create a toxic level of chemicals.

Slow-release forms of nitrogen may be advisable in sandy soils. In alkaline soils the availability of iron and manganese may be so low that certain plants exhibit the typical pale leaves with narrow (iron) or wide (manganese) darker green bands along the veins. Chelated forms of these nutrients can be applied to the soil or foliage according to the manufacturer's directions. If the trees respond to the chelated materials, a longer term and less expensive solution is to acidify the soil with sulfur.





Water Management

Young trees need adequate water to become established. Although rainfall may be adequate in some areas and in some seasons, additional water may be needed, particularly after planting when root systems are limited. After the initial watering at planting, deciduous trees do not need additional water until the first leaves have reached full size, or even later.

Pay attention to container and B&B plants that are in leaf. During the early part of their first growing season, they will need water more frequently than at the nursery. Container root balls hold less water when in the ground than in the container. And, the root system of B&B plants are greatly reduced when they leave the nursery.

At first, water the root ball and the backfill only enough to re-wet the soil. After the first few weeks, lengthen the irrigation interval. The area beyond the backfill needs to be watered only every two to three weeks. By the end of the season, the irrigation interval should be three to four weeks. Of course, rain must be taken into account. Overwatering can be as serious as under watering.

If winter rainfall has been adequate, trees should not need to be irrigated more than once a month during their second year. After that, most trees can survive with only one or no irrigations, although they would probably do better with monthly applications.

Soil Management

It is essential to maintain an area free of turf and weeds around tree trunks, because turf and weeds compete for water and nutrients, and some produce chemicals toxic to other plants. A small turf-free area around a tree also reduces the need for mowers to come close. This clear area must be at least one-foot in radius. Larger areas add little benefit. After four or five years, tree roots are extensive enough that other plants close to their trunks are not a problem, although mower operators should still exercise caution.

A three to four-inch-thick mulch, material placed on the soil surface, controls most weed seedlings. In addition, mulch protects the soil from compaction and erosion, conserves moisture, moderates soil temperatures, provides an all-weather surface for walking, and allows plants to root in the fertile and well-aerated surface soil. Keep mulches at least two inches away from the trunks of trees to minimize disease and rodent damage. A wide range of organic and inorganic materials can be used. Unfortunately, most bulky mulches are not satisfactory for trees in turf that is mown, but some plastic planting-basin covers will reduce turf and weed growth.

Power string trimmers are great for edging around borders and plants, but many trees have been fatally girdled by them. Trees are particularly vulnerable to girdling during the growing season when the cambium (the growing portion of the trunk just under the bark) is active. The cut weeds or turf return to their original more upright position obscuring the damage until the tree begins to weaken.

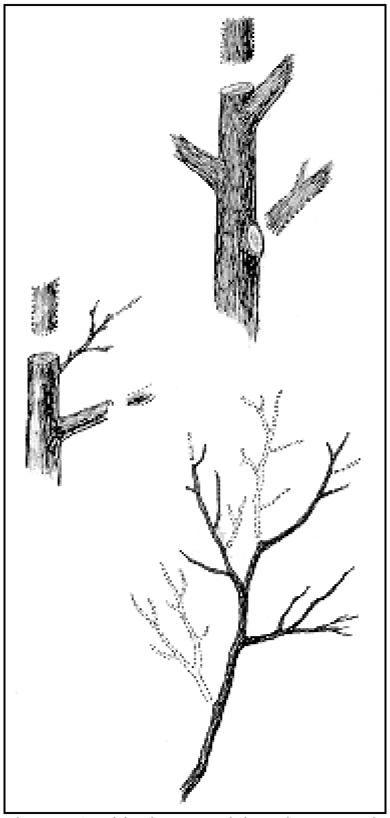


Figure 13. Thinning cuts (above) are much more desirable than heading cuts (at left).

Pest Management

Most trees get off to a good start, but serious problems can be avoided or minimized if the trees are periodically inspected. Inspect trees for the beginnings of insect and disease damage. At the same time, take care of any staking problems, do needed directive pruning, check on tree moisture status, and identify any other problems. The inspection should take only a few minutes per tree, but prompt action on any problems encountered would pay big dividends in healthier, stronger trees.

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Maintenance of Established Trees

Maintenance of established trees differs significantly from that of newly planted trees. if a young tree fails, the tree itself is lost. But, improper maintenance or neglect of an established tree may result in damage to property or people. In addition to losing the benefits of a well established tree, proper maintenance directly affects the safety, health, and welfare of urban inhabitants. Maintenance involves several categories of activities, including: scheduling, pruning, controlling insects and disease, fertilizing and aerating, as well as removing trees and stumps.

Tree Hazard Inspections

Most tree hazards can be prevented by regular checkups and proper treatments by tree professionals. To determine the scope of work, a field survey should answer thirteen questions. These questions were taken from *Alex Shigo's Tree Hazards: Your Trees Can Kill:*

1. **Target:** If the tree falls will it hit cars, houses, power lines or people? If so, the need for immediate action becomes much greater.
2. **Architecture:** Has the tree grown beyond its normal form into a dangerous form?
3. **History:** Has the tree lost large branches recently?
4. **Edge Tree:** Were neighboring trees cut away recently leaving tall trees at the edge?
5. **Dead Branches:** Are there dead tops or branches? Is the tree dead?
6. **Cracks:** Are there deep, open cracks in the trunk and branches? Cracks are major starting points for trunk and branch failures. Crack drying is just as important a factor leading to failures as over loading and decaying wood.
7. **Crotch Cracks:** Are there deep, open cracks below joining stems?
8. **Living Branches:** Do living branches bend abruptly upward or downward where tips of large branches were cut off? Living branches may pull out of trunks that are weakened by rot or cracks. Long periods of hot, dry weather may dry out the rot or cracks and weaken the union of the branch on the trunk. Beware of large branches on rotten or cracked trunks.
9. **Topping:** Are large branches growing rapidly from topping cuts on big trees? Sprouts that lean away from topping cuts have weak attachments. Sprouts near the edge of a cut may roll inward as it grows and further weaken the attachment.
10. **Storm Injury:** Are there broken branches, split trunks, or injured roots? Are branches close to power lines?
11. **Root Rot:** Are there fungus fruit bodies (mushrooms) on roots? Were roots injured by construction?
12. **Rots and Cankers:** Are there hollows or cankers (dead spots), some with fungus fruit bodies? is the tree leaning?
13. **Construction Injury:** Have roots, trunk, or branches been injured? Is there a new lawn or garden over injured roots? Water and fertilizer applied to new lawns over injured roots are absorbed by the tree's smaller, non-woody roots. The water and fertilizer stimulate the growth of the fungi that are rotting the injured woody roots. While the woody support roots grow weaker, the tree top gets larger and heavier. Once the root structure is sufficiently weakened, a moderate storm could cause the tree to fall.

Scheduling

Most public agencies use two approaches for deciding when to do tree maintenance. They respond to crisis situations that demand immediate attention, and they schedule maintenance according to a well planned program. While crises will surely occur, urban forestry programs should strive to maximize the amount of scheduled work. Usually, well managed and adequately funded programs are most efficient about scheduling.

Many urban forestry organizations in the U.S. have become victims of crisis management, responding to one unplanned situation after another. A crisis in might include: a broken limb, an uprooted tree, an obstructed stop sign, or angry people-citizens and civic leaders. Often these situations must be resolved before other maintenance can be performed. This creates an unpredictable drain on already limited resources.

Scheduled or programmed tree management allows field crews to work in predetermined zones of the city. This approach reduces transit time and increases productivity. Crews remain in a zone until all necessary work has been completed. Because they inspect each tree and perform the appropriate maintenance, the chances of a safety problem developing are significantly reduced. Street tree inventory information for a particular zone can also be gathered and updated while the crew is there.

Information from Santa Maria, California and other western cities shows that the cost per unit of maintenance is generally twice as high with crisis management as it is with the scheduled approach.

Closely related to work schedules are specifications. Because many communities have increased their use of contractors, there is a growing need for a clearly identified scope of work. Some situations lend themselves to a per unit bid and others to an hourly time and material estimate. Specifications communicate needs, form the basis of bids and serve as a standard for evaluating the quality of the completed work. In-house crews also require clearly defined expectations and objective evaluation of their work. Specifications will help them, too. When developing tree work specifications, consider the following material.

Pruning Guidelines
In writing a work plan for in-house staff or contractual specifications, the purpose and scope of pruning needs to be clearly identified.

Trees respond in predictable ways to pruning. By studying these responses arborists have developed pruning practices that preserve or enhance the beauty, structure, and function of trees.

The Western Chapter of the International Society of Arboriculture (ISA) has developed standards for pruning that provide general guidelines. Of course, each tree has a unique form and structure, so pruning needs may not always fit strict rules. However, it is the arborist that must take responsibility for special pruning practices that vary greatly from the standards. Pruning Standards is available from the Western Chapter, International Society of Arboriculture, P.O. Box 424, St. Helena, California, 94574.

The following descriptions of the various types of pruning mature trees were taken from these:

Crown cleaning or cleaning out is the removal of dead, dying, diseased, crowded, weakly attached, and low vigor branches and watersprouts for the tree crown.

Crown thinning includes crown cleaning and the selective removal of branches to increase light penetration and air movement into the crown. Greater light and air movement stimulates and maintains interior foliage, which improves branch taper and strength. Thinning reduces the wind-sail effect of the crown and the weight of heavy limbs. Thinning the crown can emphasize the structural beauty of the trunk and branches, as well as improve the growth of plants beneath the tree by increasing the light penetration.

When thinning the crown of mature trees, no more than one-quarter of the foliage should be removed. At least one-half of the remaining foliage should grow from branches that originate in the lower two-thirds of the tree. Removing laterals from a branch requires a similar approach. Try to retain inner laterals and leave the same distribution of foliage along the branch. Trees and branches pruned in this way have stress more evenly distributed.

Removing the inside lateral branches also produces an effect known as "lion's-tailing." By removing all the inner foliage, weight is moved to the ends of the branches, which may cause the branch structure to weaken and limbs to break. Greater light penetration may cause sunburned branches and stimulate watersprouts.

Crown reduction, also known as drop-crotching, decreases the height and spread of a tree. Thinning cuts will maintain the structural integrity and natural form of a tree, and delay the time when it will need to be pruned again. To make this type of cut, prune the branch back to its point of attachment or to a lateral that is at least one-half the diameter of the cut being made.

Crown restoration improves the structure and appearance of trees that have been topped or severely pruned using heading cuts. Select one to three main branch stubs that will grow to reform a more natural looking crown. Thinning or even heading may be required to match the weight of the new branches with the strength of their attachment. Restoration may require several prunings over a number of years.

Crown raising provides clearance for buildings, vehicles, pedestrians, and vistas by removing lower branches. It is important to maintain at least one-half of the tree's foliage on branches that originate in the lower two-thirds of the crown. This ensures a well-formed, tapered structure and uniformly distributed stress. When pruning for view, it's better to open "windows" through the foliage of the tree, rather than severely raising or reducing the crown.

Traffic Control

Take measures to expedite public passage through or around the work area and to prevent accidents, damage and injury. It is also important to give adequate warning to vehicles and pedestrians of any dangerous conditions that may be encountered.

Restricting traffic flow should be done only with the consent of the appropriate municipal official, such as city arborist, public works director or traffic engineer.

Tree removal should be conducted in such a manner as to insure continuous traffic flow in the street at all times. Restrict tree operations to one side of the street. Try to maintain two lanes for traffic. In situations where it possible to maintain only one lane of traffic, station flaggers at both ends of the operation area to control the flow in both directions.

Be sure to identify the agency or contractor responsible to providing traffic control personnel and equipment, such as hats and signs.

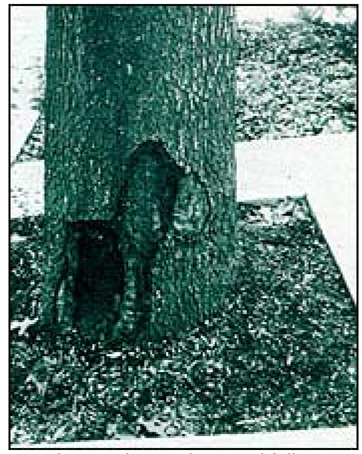
Traffic control must comply with the requirements of the American National Standards Z133 "Safety Requirements for Tree Pruning, Trimming, Repair or Removal," published by the American National Standards Institute, Inc., 1430 Broadway, New York, New York, 10018.

Insect and Disease Control

Because trees planted in urban areas are frequently subjected to hostile growing conditions, they are not always in the best of health. Trees under stress are much more susceptible to attack by harmful insects and diseases and are more likely to exhibit symptoms of the adverse environment. The type, severity and duration of a particular insect, disease or environmental problem will vary greatly, depending upon the tree's location, climate and other environmental factors. Many excellent reference texts and highly qualified local authorities can be consulted regarding specific problems. Here are some ideas to keep in mind when identifying problems and seeking advice on corrective measures.

It is a good idea to examine trees and other vegetation on a regular basis-whether or not a significant problem currently exists. These examinations help identify problems sooner, by providing a history of the plants that serves as a point of comparison when a serious problem develops.

Several types of local authorities are available for technical assistance. For free advice call on the county cooperative extension service, agricultural commissioners office and municipal parks or forestry offices. Information is also available for a nominal fee from local retail nurseries, tree services, pest control contractors or arboricultural and horticultural consultants.



Regular tree inspections and follow-up maintenance or removal are necessary to minimize potential hazards.

These experts will need information in order to diagnose the problem. Look closely at the leaves, twigs, trunk, and the ground around the tree. Are there any deformed or dead parts of the plant? Overall, how do the trees appear compared to those close by, a little farther down the street and in a completely different part of town? If the plants seem similar, chances are that any irregularities are typical of the species or locality, and may not be serious enough to treat.

If one tree is significantly different from others in the immediate area, it will be wise to check with someone. Before contacting an expert, document as many of the symptoms and as much of the tree's history as possible. Include a description of any changes in the tree's environment, such as construction, new walks, utilities, and any special treatments of the turf, ground cover or nearby vegetation.

Next, call an authority and describe any symptoms in detail. It is usually helpful to have a sample in hand when describing the problem over the telephone. If it is not possible to get a clear identification of the problem and recommendation for treatment over the telephone, the expert will have to see a fresh sample. Ask to bring a sample to the expert or ask the expert to examine the site. Expect a charge for site visits.

In preparing a sample for examination, consider several factors. The sample should be as fresh as possible and a manageable size. Label the sample with name, address and telephone number, description of the plant and its history. Try to cut the samples into pieces under a foot long and place them in a sealed plastic bag. If possible, bring normal appearing shoots as well as affected shoots. Place insects in a small bottle of rubbing alcohol, and bring along a sample of the plant they were found on. When it comes to samples, different experts may have different needs, so it will pay to ask for specific instructions and follow them closely.

If the problem sounds more complex than you expected or involves several problems simultaneously, it may be worth spending some money to have a specialist develop an assessment and annual treatment plan. This can be very cost effective, particularly when construction injury is involved, because a less detailed analysis may yield recommendations on treating the symptoms rather than the real problem.

Fertilization and Aeration

Many street trees grow in an extremely hostile environment both above and below ground. The physical, chemical, and biological conditions of the soil may need to be managed just as elements of the trees' above-ground environment are managed. Two activities-fertilization and aeration-are the primary methods of managing this area below the soil surface. Both are vital to the health and longevity of the urban forest.

Trees need adequate amounts of nutrients, water and air in the soil. Without these elements trees will grow with less vigor and will be more susceptible to secondary problems, such as attack from insects and diseases. Properly nourished trees will be more able to withstand the attack of insects and diseases and tolerate the adverse growing environment afforded by most urban situations.

Fertilizers - Plants require at least sixteen chemical elements for proper growth and development. Three of these elements-carbon, hydrogen, and oxygen-are provided by air and water. The other essential elements are obtained by the roots from soil.

The specific fertilizers applied should be based on need. Every site is different, so soil tests should be conducted every two to three years. Cooperative Extension Services can analyze samples of soil taken from each tree site and make specific recommendations.

Trees most commonly require large amounts of nitrogen. Because it is easily leached and often volatile, if necessary it may be necessary to apply nitrogen once or twice a year. Other chemical elements, such as calcium, phosphorous, potassium, and magnesium, seldom need to be added.

Acidity and alkalinity are measured on a pH scale, with lower pH indicating greater acidity. Soil pH affects the availability of certain nutrients, particularly iron and manganese, so it's important to maintain the pH between 5.5 and 7.0 for most plants.

Trees may show signs of a specific nutrient deficiency, such as interveinal chlorosis, even though soil tests indicate the presence of that nutrient. in this case, the nutrient may be present in the soil in a form that is not available to the tree. Or, nutrient uptake by trees may be inhibited by soil compaction, poor drainage or poor aeration. An analysis of the foliage may be required to determine the plants needs.

These guidelines were taken from the National Arborist Association *Standard for Fertilizing Shade and Ornamental Trees.* Be sure to study the complete NAA standards before proceeding with a fertilizer program.

Generally, the ideal time of the year to fertilize is in the late summer or fall. Fertilizer can also be applied after leaves open fully until early July. Avoid treatment with readily available inorganic nitrogen in heavy doses between July and September, because it could cause a late flush of growth that would not harden off before freezing weather.

There are a variety of methods for fertilizing trees. Fertilizers can be broadcast over the surface of the ground, poured into holes drilled into the soil, injected as a liquid into the soil, sprayed onto the leaves, or injected directly into the trunk.

Surface applications are most commonly used for fertilizers that contain only nitrogen. A properly calibrated, mechanical spreader broadcasts fertilizer over the ground in a pattern of concentric circles or linear strips beginning two or three feet from the trunk and extending five or ten feet beyond the drip line. Care should be taken to avoid excessive overlapping.

Apply fertilizer when grass is dry and then wash the grass off thoroughly with a lawn sprinkler or irrigation system. Grass blades could be burned by fertilizer that becomes slightly wet after a light rain or dew.

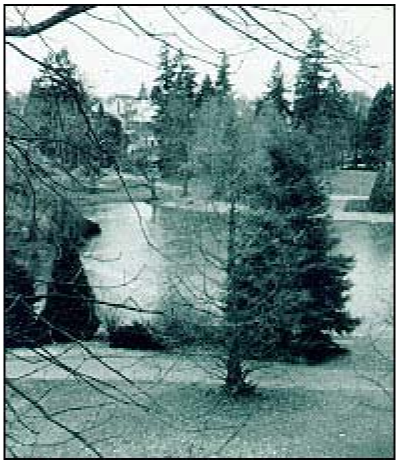
Drill holes allow relatively insoluble fertilizers, such as phosphorous, to be placed close to roots. Drill holes also provide valuable aeration in compacted soils. Arrange drill holes in concentric circles beginning about two to three feet from the tree trunk and extending five or ten feet beyond the drip line. Space the holes two to three feet apart. Drill eight to twelve inches deep, depending on the species of tree, pattern of root growth and type of soil. In compacted soil situations, it makes sense to drill deeper holes. Distribute the fertilizer uniformly among the holes after mixing it with peat moss, calcine clay, perlite, small crushed stone, sand or other appropriate soil amendment. If the area under the canopy is restricted, reduce the amount of fertilizer in proportion to the area fertilized or the number of holes drilled. Keep the fertilizer at least four inches below the surface.

If shrubs live within the root area of the tree, take care not to drill holes closer than six inches to the crown of the shrubs.

In turfed areas, the hole can be closed by pressing from different angles with the heel of a shoe, or by filling it with a plug of sod. Irrigation will help prevent injury to turf. Be careful not to flood the area, because it might bring dissolved fertilizer to the surface, injuring the turf.

Liquid injection also puts fertilizers into direct contact with tree roots. Drive the soil probe or lance eight to twelve inches into the soil. Make injections about two and one-half feet apart beginning about two to three feet from the tree trunk and working out to five or ten feet beyond the drip line. The soil lance should have three or four horizontal discharge holes in its point. Use a hydraulic sprayer that generates 100-200 pounds of pressure. inject one-half gallon of fertilizer into each hole.

Foliar spray cannot provide an adequate amount of all necessary minerals. However, spraying liquid fertilizer onto the foliage can correct minor deficiencies, especially iron. Micronutrient applications should be applied when first leaves reach full size. Within two to eight weeks, the tree should respond with greening foliage and normal bud growth on affected shoots. Species, age, time of year, soil conditions, and the severity of the deficiency will all affect the response time. One or two applications per year will generally control deficiencies, but under some conditions, maintaining healthy growth may require several treatments each year.



Trunk injections and implants are used for deficiencies in specific elements, such as iron and manganese. Trees growing where there is limited soil surface under the drip line may also need injections or implants. This treatment requires a clean, sharp drill to penetrate the bark as low as possible on the trunk. For implants, the penetration should extend into the xylem tissue. The best time for this type of fertilization is early in spring before growth starts. Wounds made at this time of year close rapidly. Trees under four inches in diameter should not receive injections or implants, Be careful not to administer injections or implants when soil moisture is low, because it may cause severe foliar burning.

Aeration - Pore spaces in the soil supply trees with air, as well as water. Some soils are naturally tight. Other soils may start out well aerated, but through the actions of pedestrians, vehicles, and even water, pore spaces are compressed. Soil compaction is far easier to prevent than it is to remedy. Preventive measures include limiting pedestrian and vehicular access, and mulching exposed soil to minimize compaction caused by the impact of rain or irrigation water.

If planting into a site with poor aeration, first rip or deep plow the soil, replace the soil with a suitable medium, or try to select trees tolerant of low soil aeration.

Mechanical aeration is possible, but at best, it's a temporary solution. Physically separating soil particles merely buys time until the pore spaces cave in again. Physical aeration is similar to the sub-surface fertilizing methods mentioned previously. An auger or high pressure water probe breaks up soil particles that have been pressed tightly together. Surface penetrations should be eight to ten inches deep two to three feet apart and extend up to one-fourth of the radius beyond the drip line of the tree. Openings should be made away from the trunk and main roots to avoid injury to the tree. For the benefit of aeration to continue, the procedure must be repeated on a regular basis Aeration may also be improved by adding an organic mulch on the soil.

Tree and Stump Removal

Trees and stumps are removed for several reasons. Tree inventory information can supply a set of criteria to guide tree removal decisions. Safety is perhaps the most important reason, and considering public liability for injuries, this becomes ample justification for removal. Trees could be removed to prevent the spread of harmful insects, disease or vegetation that may be harmful to the environment. Finally, aesthetics may dictate removing a particular tree.

As opposed to pruning, removal refers to disposing of the entire tree, including the leaves, branches, trunk, stump and major roots. When removing trees and stumps consider the following guidelines.

Stumps are defined as the lower portion of a tree-up to a maximum height of four feet-that remains after the foliage, limbs, branches, and the upper part of the trunk have been cut off.

Tree removal.

The stump removal area is generally between the sidewalk and the curb, or between the curb and another curb if growing in a median strip. For trees planted in an open space, the area for stump removal is that which causes the surface of the ground to be higher than the adjacent grade. Roots within the stump removal area should be taken out as deep as 24 inches below the finished grade. This is especially true of roots that are exposed at grade and those adjacent to or growing over a curb or sidewalk. All exposed surface roots beyond the stump area should be removed to a depth of twelve inches below grade. Soil that has been displaced by deeper roots shall be leveled to the existing grade.

The hole or depression resulting from the removal work should be filled with topsoil. Do not use chips, leaves, brush, sawdust or tree debris as filler. This organic matter would eventually decompose allowing the soil to settle. Because any type of soil will settle a little over the first several months additional soil of the same quality should be added. The entire area should be made level with the existing grade.

Stump removal.

Cleanup involves removing all soil, leaves, twigs, or trash resulting from the work. Remove debris daily to approved disposal sites. Sewer systems, landfills and ocean dumping sites are not appropriate destinations for tree debris. Depending on the nature of the material, it could be used for lumber, arts and crafts, firewood, mulch or compost.

Damage to property resulting from this work should be repaired within a reasonable time. Before starting work at a new site, survey the condition of the area, including adjacent proper ties. During clean up, survey the area again to identify damage caused by the tree work.

Cleanup activity may include brush chipping.

Overhead power lines pose a potential danger during removal operations. Exercise extreme caution to avoid damage to the lines or workers. If damage does occur, report promptly to the City Arborist, designated inspector, utility company or police department.

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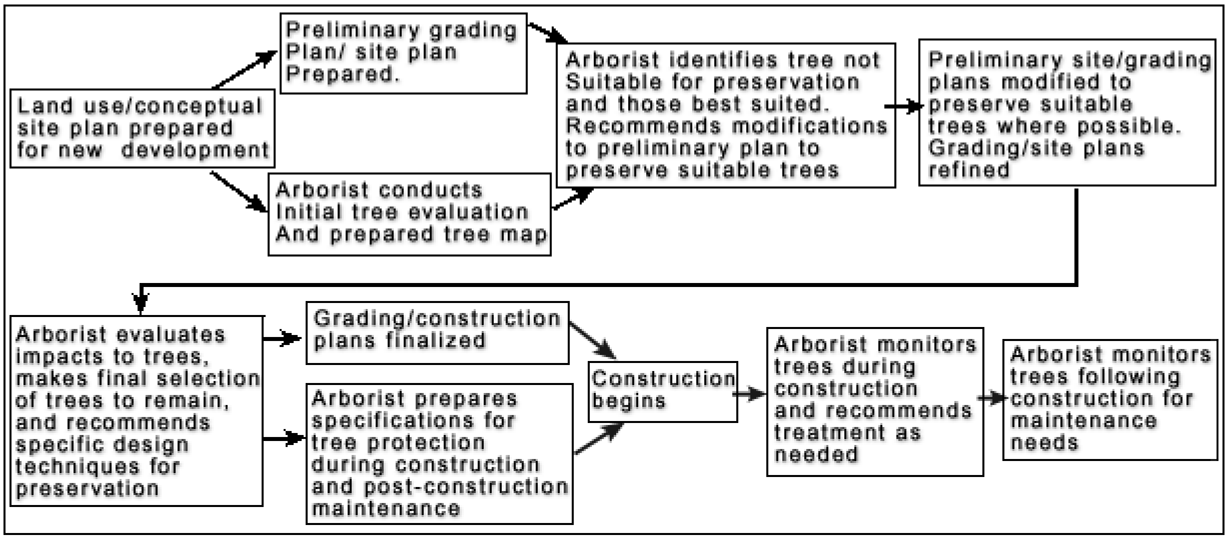
Preserving Trees Affected By Development

Mature trees provide many benefits to development sites. They enhance the aesthetic character of the area, give scale to the new buildings, provide shade, give a look of maturity to the landscape, and provide habitat for wildlife. it may be possible to retain trees with minimum forethought. However, preserving specimens that will survive and perform well in the new environment requires thorough planning, careful implementation, and adequate maintenance.

Effective tree protection is a long process. First, evaluate the trees to determine which specimens are suitable for preservation. Next, work with the planners and engineers to design improvements so that suitable trees are preserved. Then, monitor construction around the trees to see that the trees are not injured. Finally, routinely evaluate the trees to identify maintenance needs.



Identifying Trees to be Protected

Deciding which trees to preserve, and designing development around them often seems like a 'chicken or the egg' problem. The trees suitable for preservation must be identified before designing around them. On the other hand, the design strongly influences the selection of trees to be preserved.

One way out of this dilemma involves a preliminary evaluation of the trees to determine those that are suitable for preservation. Compare that information with conceptual site plans. Identify the trees suitable for saving, and modify the site plan to accommodate the desirable trees. Finally, work out the details of grading and preservation for trees that will remain (Fig. 14).

In most cases the costs to preserve trees are significant. Costs accrue because the land dedicated for tree preservation is unavailable for building, structures, and techniques to minimize damage to trees require extra design and construction attention, and affected trees must be maintained to support long-term health. These costs will be borne by the public, whether through increased taxes to pay for trees in public rights-of-way, higher homeowner association dues, greater commercial rents, higher home prices or direct payment for maintenance. Trees should be selected carefully, keeping their value and contribution to the new environment in mind.

In determining which trees are to be preserved, four factors must be considered:

— Suitability of the species to the new land use;

— Tree health and structural stability;

— Species tolerance to changes in environment; and

— Level of maintenance that will be provided following impact.

Species Suitability - The suitability of the species to the location and use of the site are important factors in determining whether to save a tree or not. For example, species that normally grow along streams, such as willow and alder, would perform poorly in a parking lot.

The tree should survive in the new landscape for a considerable length of time to warrant the cost and effort of protection. An oak that can be expected to survive for many decades has a greater value than a mature acacia that may only live for a few years.

Tree Health - Young, vigorous, healthy trees are the best candidates for protection, because they grow new tissue quickly and adapt readily to new environments. However, it is large, old trees that are most often the focus of preservation. Of course, it is possible to preserve old trees as long as they are healthy, but younger ones may give the best return on investment.

Vigorous trees usually have full canopies and healthy leaves. Three conditions indicate poor tree health. First, the leaves are small and pale for the species. Second, some of the branches are dead. Finally, most of the foliage arises from short twigs along the major limbs, known as epicormic growth. Trees with large cavities or other structural weaknesses are not good candidates for preservation, unless the problems can be alleviated by pruning, cabling or bracing.

Tolerance To Changes In Environment - The ability of the tree to tolerate injury and changes in the environment is another important factor to consider. Trees that regenerate roots quickly and have adaptations to control water loss seem to be better able to tolerate construction impacts.

For example, coast live oak (Quercus agrifolia), which has a stiff, cupped leaf with a thick cuticle, tolerates greater root injury than California black walnut (Juglans hindsii), which has a smooth, thin leaf. On the other hand, willows, which also have smooth, thin leaves, typically adapt well to new environments, because they have the ability to regenerate new roots quickly.

Environmental changes can cause tree decline even when the tree is not directly injured. Significant changes in water table levels or rechannelization of streams or runoff can seriously weaken or kill trees. Road fills placed over stream beds can raise water levels upstream. It is important to consider large scale alterations in the overall ecology of the area, as well as the specific changes that will occur next to trees.

Level Of Maintenance That Will Be Provided - Trees stressed by construction require considerable maintenance to prevent loss of vigor and attack by harmful insects and diseases. Irrigation, fertilization, pest and disease control, and pruning are all aspects of this maintenance. For example, Monterey pine trees (Pinus radiata) stressed by root injury may require regular irrigation and spraying for bark beetles or other insects. If those treatments cannot be provided, it may be better to remove the trees rather than trying to preserve them.

Responsibilities for maintenance of affected trees should be established early in the planning phase. If the trees will not be maintained, it is important to minimize stresses to the trees that would affect tree health.

Preparing a Tree Location Map

A tree location map is critical to successful preservation. Use a topographic map showing vegetation lines as a base. Early in the design process locate the trunks approximately. Later, the engineer's survey can pinpoint the locations and show the base elevation of the trunks. The engineer should project to the center line of the tree when plotting locations. An indication of the dripline for each tree would also be helpful. On 20-scale or larger maps, plot the circumference of the trunk for larger trees.

Be sure that tree locations show on all building site plans. Number the trees on the map so that all discussions can address specific trees. It is helpful to have a corresponding numbered tag attached to the tree, as well.

Assessing Potential Impacts to Trees

Evaluate the development plans around the trees to estimate the potential impact. This requires skill in reading plans and an understanding of construction procedures. The following plans and specifications should be reviewed:

— Topography and tree survey plan;

— Grading plan and specifications;

— Plot or development plan;

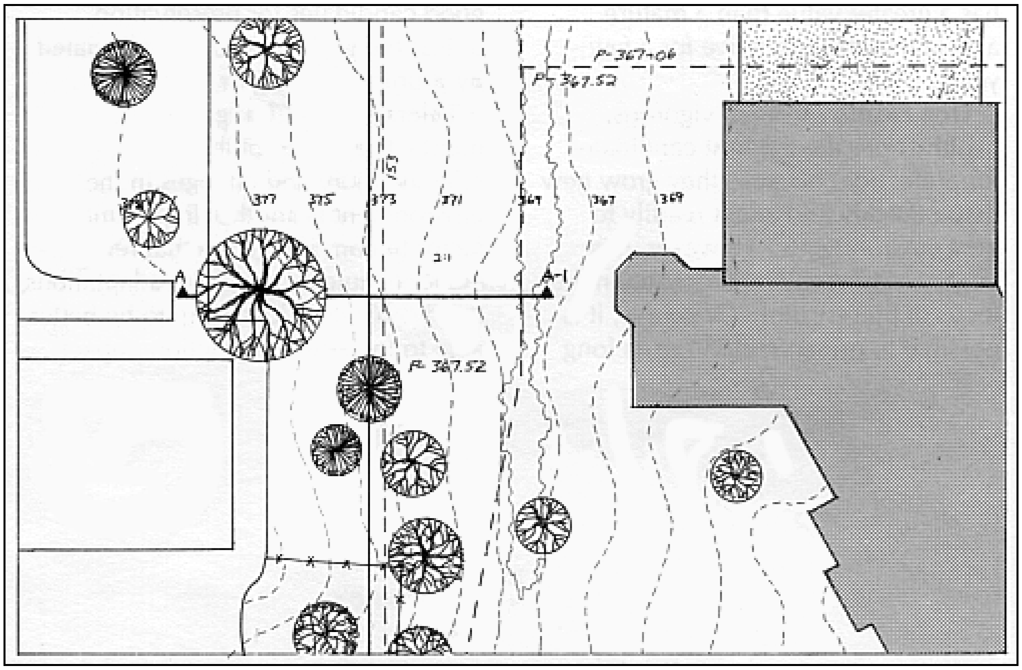
— Utilities placement and depth;

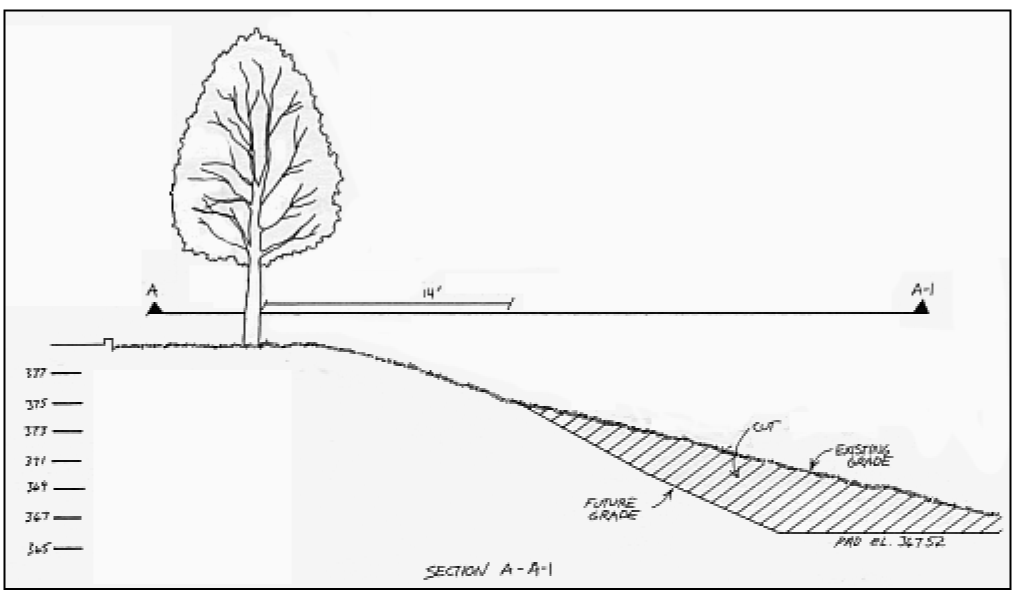
— Drainage plan; and

Geotechnical survey.

The plans will provide information on the depth of cuts, fills, utilities, subdrains, and other excavations, as well as their distance from trees. The geotechnical survey describes the soil profile. It also specifies the compaction and over-excavation required under structures, pavement, and fills.

To better visualize the changes that will occur next to trees, draw cross-sectional views showing existing and future grades, and all improvements (Fig. 15). Based on the geotechnical requirements, the amount of soil work could also be estimated and recorded on the drawing.





Soil Alterations During Construction

Soil favorable for root growth is a mixture of mineral particles, organic matter, air and water. About half of the volume of the soil is pore space containing varying amounts of water and air. To soil engineers pore spaces are known as voids. Although an asset to plant growth, voids reduce a soil's value as structural material. To stabilize the soil, engineers compact it to remove as many of the voids as possible. Compacting soils for construction involves removing the soil to a specified depth, mixing the soil with water, and replacing the soil in thin lifts (usually six to eight inches thick). Heavy equipment, designed to maximize the compaction, drives repeatedly over each lift. This activity hurts tree roots by first cutting them, and then by breaking down the soil structure.

Location of Tree Roots

To protect tree roots from damage, it is important to know where to look for them. Although root systems are often depicted as mirror images of the tops, they usually cover a much larger area. Roots can extend far beyond the dripline, as much as two to three times the diameter of the crown. The major portion of the absorbing roots system of a mature tree is within the top three feet of soil, and most of the fine roots active in water and nutrient absorption are in the top twelve inches (Fig. 16). Many trees form vertical sinker roots that arise from larger horizontal roots near the trunk of the tree. Sinker roots aid in water and nutrient absorption from deeper layers of aerated soil during times of drought.

Root patterns also are affected by topography and characteristics of the soil or substrate. Trees on slopes tend to have more roots on the downhill side. Roots of trees along streams will parallel the bank.

Developing a site is seldom possible without hurting tree roots to some extent. Even preliminary grading, stripping the site of debris and organic laden topsoil, can cause significant root damage. It is commonly thought that a healthy tree tolerates removal of one-third of its roots. Most guidelines for tree preservation advise holding construction and grading outside of the dripline. However, based on a typical root structure, even that restriction could lead to removal of over half the tree's roots. As land values rise, there is more pressure to encroach within the dripline to gain usable space.

Several variables affect a tree's ability to tolerate encroachment, including the health, species, root structure and environmental factors. The type of construction that will occur and how it will be executed are equally important factors. For example, construction of a concrete sidewalk on natural grade requires about six inches of excavation. This would cause less injury than an asphalt road requiring at least twelve inches of excavation. A road with water and sewer improvements along the curb-usually in trenches four to six feet deep- must be held farther away from trees than one with no improvements.

If work must be done close to trees, extra care can minimize the damage. For example, lowering the grade two feet at a distance fifteen feet from the trunk of a tree that forms sinker roots may be possible. But it would require that the excavation be done by hand and the roots cut cleanly with a saw, rather than with equipment that rips and shatters roots.

Evaluating the potential of trees to survive and adapt to the new environment must be made on a tree-by-tree basis. The evaluation involves estimating the percentage of root loss, the potential of the tree to tolerate immediate water stress, and the ability of the tree to produce new roots.

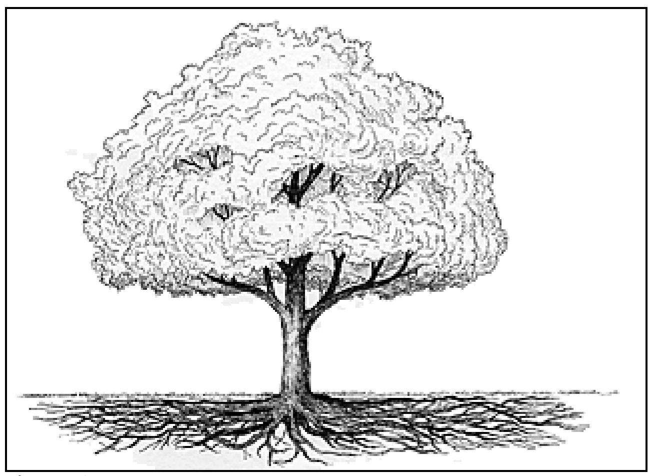


Figure 16

Tree Preservation Techniques

Major construction impacts and techniques to minimize them are described in Table 1. Following is a discussion of the major points to consider in design and construction.

Preserving Trees in Groups -Whenever possible, preserve trees in groups so that relatively large areas can be set aside for native vegetation. These areas serve as green belts or open space. In forest situations the amount of thinning the trees will tolerate depends on the size, age and species present. Mixed forest stands, which contain conifers and hardwoods of different ages and sizes, should be preserved in large blocks (at least 60 feet wide).

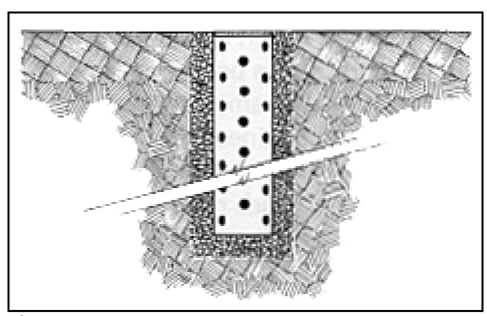


Figure 17.

On the other hand, single oaks growing in the open can often be preserved effectively.

If only a small amount of land can be dedicated to tree preservation, it may be better to allot a larger area around the few best specimens than to attempt saving a greater number of trees that would sustain heavy damage.

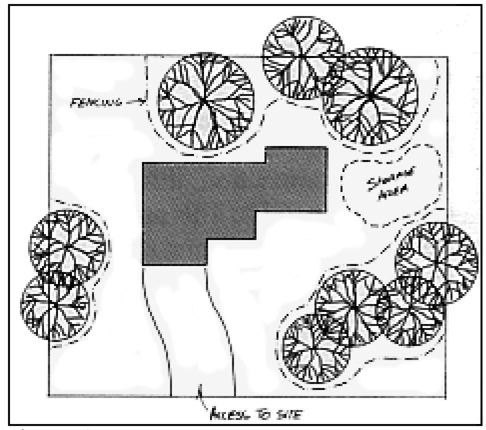
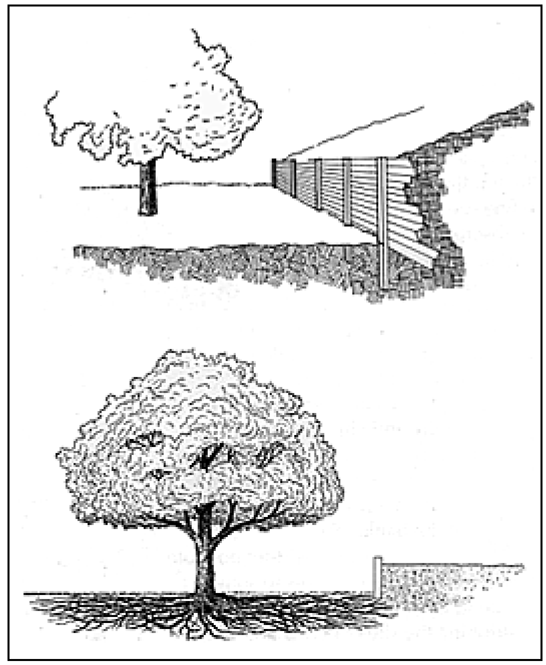


Figure 18.

Site Preparation and Clearing Specifications - Clearly identify the trees to be preserved on all plans. Flag and fence them in the field. When next to trees that will remain, trees to be removed should be cut rather than pushed over with equipment. This avoids possible root damage to remaining trees.



Specify no stripping of top soil or grubbing of understory in tree preservation zones.

Locate storage for equipment and materials, access roads to the site, and traffic patterns within the site well away from trees to avoid unnecessary root injury and soil compaction. These areas should be identified on the site plans (Fig. 18).

Protecting Trees from Fill - Few trees can tolerate having fill soil placed over their trunks. Furthermore, the soil work involved in placing a fill causes root damage and creates an environment unfavorable for new root development (see Table 1).

The following treatments can minimize the adverse effects of fill:

- Hold fill away from the tree with a retaining wall designed with a discontinuous footing (Fig. 19 & 20).
- Unless the fill will support a structure, ask the soil engineer to specify the minimum soil compaction (usually about 85 percent).
- If fill will be imported, provide specifications for the chemical characteristics of the soil, so that trees will not be harmed by toxic conditions, such as high salts. Engineering specifications usually cover only the physical properties of the soil
- For fill covering large portions of the roots, consider installing an aeration system on natural grade prior to placing the fill. If the potential for soil subsidence is a problem, air vents can be installed through the fill into natural grade after construction is complete (Fig. 17).

Table 1: Major Construction Impacts and Methods to Minimize Damage

IMPACT TO TREE	CONSTRUCTION ACTIVITY	METHODS/TREATMENTS TO MINIMIZE DAMAGE
Root loss	Stripping site of organic surface soil during mass grading	Restrict stripping of topsoil around trees. Any woody vegetation to be removed adjacent to trees to remain should be cut at ground level and not pulled out by equipment, or root injury to remaining trees may result.
	Lowering grade, scarifying, preparing subgrade for fills, structures	Use retaining walls with discontinuous footings to maintain natural grade as far as possible from trees (Fig. 21 & 22). Excavate to finish grade by hand and cut exposed roots with a saw to avoid root wrenching and shattering by equipment, or cut with root pruning equipment. Spoil beyond cut face can be removed by equipment sitting outside the dripline of the tree.
	Subgrade preparation for pavement	Use paving materials requiring a minimum amount of excavation (e.g. reinforced concrete instead of asphalt). Design traffic patterns to avoid heavy loads adjacent to trees (heavy load bearing pavement require thicker base material and subgrade compaction). Specify minimum subgrade compaction under pavement within dripline (extra reinforcement in concrete or geotextile under asphalt may be needed).
	Excavation for footings, walls, foundations	Design walls/structures with discontinuous footings, pier foundations (Fig. 22). Excavate by hand. Avoid slab foundations, post and beam footings.
	Trenching for utilities, drainage	Coordinate utility trench locations with installation contractors. Consolidate utility trenches. Excavate trenches by hand in areas with roots larger than 1" diameter. Tunnel under woody roots rather than cutting them.
Wounding top of tree	Injury from equipment	Fence trees to enclose low branches and protect trunk. Report all damage promptly so arborists can treat appropriately.
	Pruning for vertical clearance for building, traffic, and construction equipment	Prune to minimum height required prior to construction. Consider minimum height requirements of construction equipment and emergency vehicles over roads. All pruning should be performed by an arborist, not by construction personnel.
Unfavorable conditions for root growth; chronic stress from reduced root systems	Compacted soils	Fence trees to keep traffic and storage out of root area. In areas of engineered fills, specify minimum compaction (usually 85%) if fill will not support a structure. Provide a storage yard and traffic areas for construction activity well away from trees. Protect soil surface from traffic compaction with thick mulch. Following construction, vertical mulch compacted areas. Install aeration vents (Fig. 17).
	Spills, waste disposal (e.g. paint, oil, fuel)	Post notices on fences prohibiting dumping and disposal of waste around trees. Require immediate cleanup of accidental spills.

Lowering the Grade - Obviously, root damage occurs when soil is stripped away to lower the grade. Here are a few ways to minimize the damage that occurs:

- Keep cuts as far from trees as possible by installing retaining walls. If the cut is greater than three feet, a continuous footing can be used because few roots are encountered below that depth. For shallow cuts, use discontinuous footings to minimize root injury (Fig. 21 & 22).
- Excavate by hand at the cut face, cutting the exposed roots cleanly with a saw. Once the trench has been dug to the depth of the finish grade a backhoe can be used to pull away the soil. The backhoe should sit outside the dripline and remove the soil to finish grade.

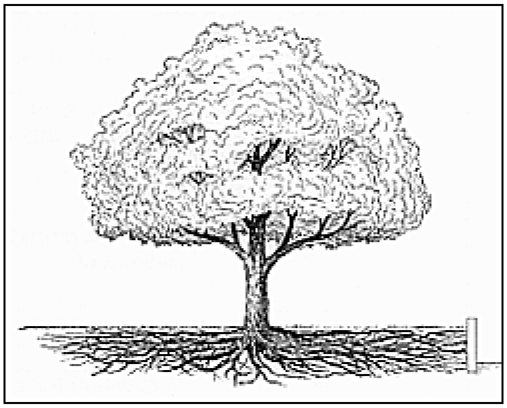


Figure 21.

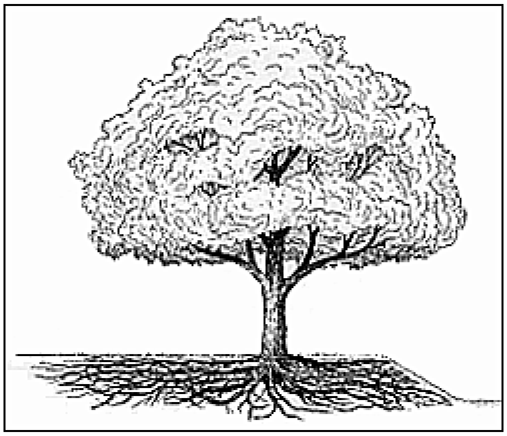


Figure 22.

Paving - Paving inflicts more extensive root damage than might be expected. Because it is often considered a structure, pavement requires soil compaction similar to buildings. Excavation must be deep enough to accommodate the compacted sub grade, the base material, and the pavement itself. To minimize damage caused by paving:

- Maintain an area of several feet around the base of the trunk free of all pavement. Mulch the soil surface.
- Use paving materials that allow water to penetrate, such as inter locking bricks on sand, where possible over the root zone of trees.

- Avoid excavation into the root zone by placing base material and pavement on natural grade, making the level of the pavement higher than the tree flair (Fig. 23). Make sure water will not collect in the well surrounding the tree.
- Install aeration vents in impervious pavement (Fig. 24).

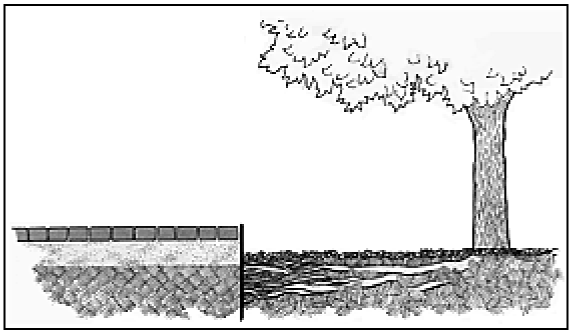


Figure 23.

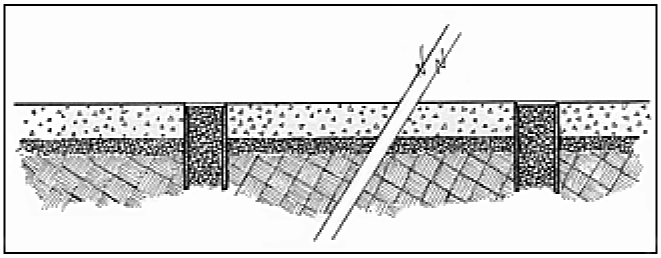


Figure 24.

Utilities and Street Improvements - Underground utilities are often overlooked as a possible cause of root injury. Water and sewer main lines are usually placed just inside the curb and gutter during road construction. Depth requirements vary, but four to six feet deep is typical. Contractors connect buildings to utility lines and take the shortest and straightest path, unless otherwise instructed. These connections are usually placed in trenches three feet deep. Consider the following methods to minimize damage from installation of utilities:

- Place notices on tree protection fences informing workers to prevent encroachment by routing all trenches around trees.

- Trench by hand when digging close to trees, so the woody roots can be bridged, or tunnel under tree roots.
- Curve trenches for street improvements towards the middle of the road or move them to the other side of the street.

Post-Construction Site Re-Assessment

Once construction is complete and the site clean, the tree care professional begins to direct maintenance. The remaining trees were chosen by others in the development process, and the reasons for selecting them may not be known. If protection measures were applied, they may be hidden. So, before post-construction maintenance can begin, the tree care professional must re-assess the condition of the site.

Begin by determining the condition of the trees and sites. Safety, value to the property, and the chances of remaining vigorous are all factors with considering. The maintenance prescription should compensate fore construction damage, including: disruptions to drainage, restricting surfaces, impacts of fill, and interference with the trees.

Trees stressed by construction must be carefully maintained to avoid loss of vigor or attack by harmful insects and disease. They require special attention to irrigation, fertilization, pruning, and pest control. In extreme cases, improper preservation techniques or severe construction damage could prompt heavy pruning—or even removal of whole tree. To determine the need for and the practicality of restoring a site severely changed by construction, the tree manager should draw on information from building plans as well as the designers and contractors involved in construction

Damage or modification to the above-ground portion of the trees is easy to detect. Impacts to the roots and soil are more common, but generally difficult to uncover. These impacts are too often overlooked. Be sure to consider all factors affecting tree health, before developing a maintenance plan.

Table 2: Typical Grading and Construction Specifications and Terms

TERM	DESCRIPTION
Stripping	Removal of all surface vegetation, organic laden topsoil, and debris, usually 6-12" depth. Often results in removal of soil through the major rootzone.
Scarification	Subsurface preparation under fills and slabs by loosening soil, usually to a depth of 6-12", then recompacting to 90-95%.
Percent compaction	The ratio of the fill material as compacted in the field to the maximum dry density of the same material, expressed as a percentage of the dry density.
Fill	Soil or rock material placed to raise the natural grade of the site or to backfill excavations (including trenches).
Engineered fill or compacted fill	Fill subjected to geotechnical engineering tests for proper compaction. Required percentage of compaction is created through the depth of the fill by spreading the fill material in uniform lifts not exceeding 6-8" in uncompacted thickness. Each layer (lift) is brought to a water content at or near the laboratory optimum and compacted with heavy equipment. 90-97% compaction is usually required.
Pavement	A typical pavement section for roads includes 2-5" of asphalt pavement, underlain with 8-20" of compacted aggregate base, placed on 6-12" of compacted subgrade. Concrete pavements usually require less excavation.
Slopes	The engineer determines the maximum steepness of cut and fill slopes (e.g. 2:1, 3:1). Fills on or against existing slopes are placed on horizontal benches cut into the slope. The toe of the slope may be keyed into native soils by cutting into the native grade 3 to 5 feet.
Foundations	Soils with potential for expansion can exert significant uplift pressures on shallow foundations and pavements. Foundations and slab-on-grade floors may need to be supported on sections of engineered fill, requiring excavation into the native grade.
Footings	Footings anchor walls. There are several types of footings, but most are continuous and are about 12-18" deep and 18-24" wide. Discontinuous footings can be designed for most walls and foundations. These rely on deep pillar type supports in holes drilled several feet deep and several feet apart. Minimum root damage will occur if the major woody roots are located and the pillars spaced to avoid them.
Street improvements	These include sewer, storm drains, and water lines. They are usually placed in trenches 4 to 6 feet deep along the edges of roads. Sewer and water lines must be placed some minimum distance apart according to local requirements.

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Utility Arboriculture

Local utilities generally prune more trees in public rights-of-way than all other parties combined. And, underground services have a similar impact. Trees and overhead lines have been getting in each other's way ever since the first utility pole was erected along a tree lined street. Initially, trees were considered obstructions to the electrification of a nation. Lines were built and the public got electric power, often at the expense of trees.

It should come as no surprise, that the public has long complained about the seeming insensitivity to trees displayed by utility pruning programs. At the same time, utility arborists have legitimate objections about common tree planting practices in utility rights-of-way. Both trees and overhead lines have a legitimate place in human communities. For this reason, it is prudent for every community to take a close look at the practices of local utility companies and the way those practices affect the urban forest. To develop a constructive working relationship, it's important to understand the opportunities for cooperation as well as conflict. Minimizing conflicts requires an examination of the goals and objectives of each function.

Purpose
The local utility company is responsible for maintaining safe and reliable electrical service to its customers. Trees growing near overhead lines can pose a threat to reliability and public safety, so trimming and removing trees along the "utility strip" is one important utility function. Simply put, utilities manage the portion of the urban forest growing near overhead power lines. However, the community is responsible for maintaining and preserving all components of the urban forest, including parks, greenways, and street trees growing in the "utility strip."

Attitude
A municipal arborist views the urban tree as a generalist; each tree is a valuable and integral part of the entire urban forest. Condition, vigor, size, and maintenance needs are items that require attention for the good of the community. On the other hand, a utility arborist focuses on trees as they relate to overhead lines. The goal of a utilities tree trimming efforts is that clearance be obtained between the power lines and the trees. When the need for line clearance work is assessed, the decision to trim or remove is made from that perspective. Work closely with your local utility to broaden priorities and benefit the urban forest as well as the utility system.

Approach
Some utilities have developed vegetation management plans, which are similar to municipal street tree management plans. Before scheduled maintenance is performed, a crew conducts a pre-job survey of the tree work along the line. This inventory identifies the amount of trimming and tree removal work required. Inventory information also helps allocate labor and equipment resources, and establish crew makeup and work practices.


"Round-over" or "topping" techniques of pruning are not acceptable standards for tree trimming.

Planting inappropriate tree species under power lines creates a difficult situation for both the utility and the community. For example, trying to control the height of trees with the genetic drive to grow eighty feet tall poses a real maintenance challenge. As long as the wrong trees are planted in the wrong place, utilities will be obligated to prune them or remove them altogether. To minimize this, many utilities have developed tree lists suggesting alternatives to such favorites as oaks, maples, London plane trees, and other tall-growing species. The recommended species are selected for low maintenance, insect and disease resistance, availability, and beauty. Mature height must be 25 feet or less.

Normally, the utility's vegetation management budget is significantly larger than the community's urban forestry budget. Cooperation allows both organizations to extend their resources. In large and small communities alike, utility efforts represent the most significant force for change in the urban forest. Where a community lacks resources, a cooperative effort may represent the only way to manage the urban forest.

In many communities, a history of cooperation exists between the local utilities and government agencies. For example, cooperation was common during efforts to remove elm trees during the peak of the Dutch elm disease in the late 1960's and early 1970's. If such a relationship does not exist, one should be initiated immediately.

Cooperation occurs in situations where both parties benefit by working together. In many cities, the continual decline of "old growth, even age" trees along streets and in parks poses a hazard recognized by both utilities and communities. But, this situation also presents an opportunity to improve the composition of the urban forest through a cooperative program of tree removal and replacement. Selectively removing the overlymature trees and replanting with more desirable species-those more compatible with urban conditions-creates a new urban forest.

Conflicting ideas will not disappear overnight. For example, it may be difficult to reconcile the public's desire for streets shaded by majestic trees with the utility's need to eliminate interference between trees and overhead lines. Where appropriate small scale street trees can be integrated into the community's planting plan. In other cases, pruning practices that appeal to community aesthetics may be needed. Overall, a joint effort will lead to a compromise that comes closest to meeting the needs of both groups.

Common Concerns

In many communities, trees are caught between utilities trimming from the top down and communities trimming from the bottom up. This creates serious problems for the trees. Maintaining reliable and safe service is the main mission of utilities, and it requires clearance between trees and distribution lines.

While not universally practiced, many utility companies continue the practice of "topping" or "round-over" pruning. This technique describes a method of pruning where cuts are made at arbitrary points on a branch along a uniform plane within the crown. The resulting crown form is artificially uniform following pruning. Unfortunately, topping causes more problems than it solves. Because the tree sprouts grow rapidly, the tree must be pruned frequently.

Two commonly accepted pruning alternatives are "lateral drop crotch pruning," also known as "natural pruning," and "side-pruning." Lateral or natural pruning requires the tree trimmer to pick out the branches growing toward the lines and remove them where they attach to the next lateral limb. Properly placed cuts produce few sprouts and natural growth rates. The next cycle of trimming requires fewer cuts than the topping approach, because the problem branches were removed during the previous cycle and sprout growth has been slower. This method is used both on trees growing beneath or to the side of utility lines.

When the wrong species has been planted directly underneath the power lines, there may be no other alternative short of removal and replanting.

Increasingly, utilities install underground distribution lines that require trenches. These trenches frequently damage tree roots, which slows tree growth, and leads to decline of the crown and root system. Branches may die, increasing the chances of wind damage and invasion of wood decaying fungi or insects. Augering, tunneling, or boring through the root zone of the tree will cause less damage to the root system.

Safety and liability are issues of concern to everyone. Dead or dying trees in a park or along a street will eventually fall, possibly causing injuries or fatalities. If such trees are close to overhead power lines, their failure could tear down lines and poles, causing outages and other damage. Trees with low branches may tempt climbers and pose a safety concern. Someone climbing into the crown of the tree, particularly a child, risks touching a high voltage wire and suffering serious injury or death. Vehicular and pedestrian traffic is another concern. Street trees must be managed to ensure visibility and clearance for street lights and signs.


Height reduction pruning by "topping" causes more problems than it solves.

Coordination

The utility and the community are both responsible to the public. By working together they can obtain better results than by working alone. Communication is the key. Coordinating work plans and schedules increases efficiency. And, cooperation reduces the need for restrictive municipal regulations.


Height reduction pruning using this "natural" or "drop crotch" technique is the correct way to "top" a tree.

Through cooperation the utility will become more aware of the impacts that their operations have on the urban forest. Utilities with a negative image-whether justified or not- may be eager to demonstrate their helpful attitude.

Through cooperative efforts, utilities are becoming more sensitive to the value of incorporating sound, arboriculture techniques into their vegetation management programs. And, municipal arborists are beginning to recognize utilities as an arboriculturally.

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The Politics of Trees

The purpose of this guide is primarily to provide both professional and nonprofessionals with easily understood technical information on proper tree management. While information is important, having the opportunity to apply this knowledge is even more important. Successful urban forestry programs around the nation have something in common. They exercise the political process to attain their goals.

Urban forestry professionals feel much more comfortable dealing with technical subjects based on clear and widely accepted principles. However, the political process often fails to respond to clear principles, making it difficult to understand and hard to control. It's no surprise that technically competent people sometimes choose to avoid politics. But without some political involvement, it is unlikely that tree programs will receive the support they need. The following section highlights the basic elements of decision making that affect trees in urban areas.

Decision-Making Process

Local decision making is seldom a transparent process, so it is important to be prepared. Begin by identifying a goal: to save a group of trees threatened by new construction; to provide additional funding for a tree planting program; or, to implement a hazardous tree removal program. Reconnaissance is next. Identify key players and their roles. The roles may be technical, financial, or administrative. Determine the person or people who will make the final decision. Match peoples' roles with the goal, so that energy and resources can be focused on people who have influence in the appropriate area. Devise a strategy. Decide how best to persuade the decision makers.

A successful strategy usually includes gathering and distributing information. Identify technical experts who are credible to all concerned parties. They provide the objective technical information. Early in the process, give this information to decision makers. This allows everyone a chance to review the information and ask questions. When the time comes, the decision will have been made after careful consideration, and not on the spur of the moment. Communication is one of the keys to success.

In local governments, the staff who implement policies are frequently consulted by decision-makers. The staff is also a good source of advice for citizens. They can point out major obstacles or opponents. Overcoming the obstacles may mean doing research, answering questions, or meeting with people. But, once this is done there is a much greater chance of receiving approval. Luckily, trees fall into the "motherhood and apple pie category," and people have difficulty not supporting them.

Some goals could be achieved administratively, saving the effort to develop and implement a legislative solution. Local government staff, especially planners, can be allies. They are generally supportive of actions that improve the liveability of the community, particularly trees and other types of landscaping. For example, planners often include street tree requirements in zoning codes. Let them know that a vocal, citizens group favors this approach and will support them, with elected officials, if necessary.

On the other hand, staff may see problems implementing the proposal and try to discourage the effort. Thank them for their help and advice, but inform them that the goal will be pursued anyway. The appeal could then be taken to a higher authority. And, if the system does not work, work outside the system. Some wonderful accomplishments have been achieved by citizens who diligently refused to take "no" for an answer.

Local officials are often swayed by organized movements, even though they may actually be quite small. Encourage distinguished citizens, such as doctors, lawyers, and businessmen to endorse the cause, so the organization represents the entire community. Identify well-known people with important titles, such as Ph.D., M.D. and J.D., as supporters of the proposal. Stationery listing the Board of Governors in the margin communicates the organization's seriousness and commitment. Looking as professional as possible always helps to establish credibility.

When influential people support the tree proposal, they should be thanked publicly. The organization could issue a news release identifying the good works of the individual or present an award. Whatever the method, make sure the community knows about those people that helped the effort. Most policy decisions are made at public meetings, and a good showing of support is critical to achieving a favorable outcome. Encourage friends, relatives, neighbors, and the general public to attend-the more the better.

Select several articulate and well-dressed people to endorse the proposal on behalf of the group. And, remember the most credible and influential people: "voters who care about what is going to happen to their trees." Occasionally, more than one appearance may be necessary.

Even though it may seem that the odds are long, there are many examples of successful campaigns that operated on a shoestring. Well directed efforts taking a few days and less than $100 have launched tree programs costing hundreds of thousands of dollars. A small effort could result in substantial long term benefits to the community.

Once the policy decision has been made, the easy part is over. Implementing the policy will require continued involvement from the group that promoted it. They must remain visible to support and monitor implementation. Support of the staff who will be implementing the policy will be helpful.

Technical vs. Value Decisions

Tree management frequently offers several alternatives for action, and weighing them can be difficult. The dilemma often arises from trying to balance two types of considerations. Some factors can be measured, such as size, shape, condition, health, and cost. Others are intangible values, such as beauty, history, attitude, and aesthetics. Urban forestry professionals often find themselves balancing tangible factors against intangible ones. For example, preserving existing trees during development must often be compared to the value of the trees and their chances of surviving construction. Communities often require a developer to spend hundreds of dollars preserving a tree that becomes damaged. It is worth less than the cost to preserve it, and then it dies a year or two after the project is completed. There is no formula for arriving at the best solution. Only professional judgement, honed by experience and tempered with public input, can make these decisions.

Liability

Trees pose some unique liability problems. While most trees cause few problems, there are occasions where problems can be significant and should be avoided if possible. Liability problems can best be avoided by clearly assigning responsibility for a tree's care. Visual clearance for traffic signals must be maintained. Dead wood or hazardous trees on public property must be removed. And, property damage resulting from trees, such as broken sidewalks, must be repaired.

Scheduled tree maintenance programs limit liability to some extent by minimizing the number of dangerous situations that develop. Such a program can also maximize the benefits from trees by educating people, regulating tree care activities, and providing some central organization to undertake this task.

A number of communities have attempted to pass liability for trees to adjacent property owners, while retaining regulatory authority over anything done to the trees. While the stated purpose of this action is to eliminate the community's liability for trees, it cannot be accomplished in this manner. At most, the property owner shares liability with the local government.

Coordination

As a community resource, trees may come under the jurisdictions of various groups. Although often overlooked, one task for urban forestry programs is coordinating the activities of others. Coordination is needed in three situations: public/public, public/ private and private/private.

Public/Public - Any public tree care agency is regularly faced with adverse effects from other public agencies who have responsibilities for things such as sewer systems, street rights-of-way and overhead utility lines. This is also true of different departments within the same public agency. Lack of attention to the work of others can be so damaging that it may outweigh the good work done by the urban forestry program. It is essential that one department coordinate all tree-related activities on public property, if the tree resources are to be protected. Since the tree care programs in most areas suffer from a lack of funds, it helps to establish good informal working relationships with other groups. In one city, the department of public works, which removed a number of trees in order to widen a city street, decided to replant new trees as part of the project. They did this based solely on the encouragement of the forestry department. The neighborhood was delighted with the result.

Public/Public - This is probably the most typical situation in many municipalities. Coordination often comes in the form of a permit system. Any tree work, such as pruning, planting, and applying pesticides, requires a permit. Such a system coordinates the activities of homeowners, businesses, tree care contractors, utility companies, and developers. Some cities even extend this regulation to private property by requiring a permit to remove any tree over a certain size, usually four to six inches diameter. Since it affects the largest percentage of the urban forest, public/private coordination will have the greatest benefits.

Public/Public - This type of effort addresses what private property owners do to their trees. It is difficult to play as direct a role as in the previous two examples, but it is still worth considering. Private/private coordination fills the remaining pieces of the urban forest, and allows a comprehensive approach to management.

Public education campaigns can stress the value of trees to the community, their contribution to property values, environmental benefits, and economic contributions. Other topics could be more technical: proper tree care procedures, choosing a reputable tree care company, and minimizing the liability.

This role is more "facilitation" than the direct regulation or coordination mentioned earlier. This role could be played by either a public agency or a private non-profit group, such as Tree People in Los Angeles, California. A number of communities in British Columbia, Oregon, Washington, and California cultivate community spirit to encourage private individuals to preserve historic and otherwise significant trees.

Remember that maintaining and preserving the urban forest for future generations is a big job-more than one person can do alone. Success will require cooperation and coordination among many people. The more people involved the more successful the effort will be.

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